As our older population increases worldwide and society looks to the future, health policy and public health issues concerning the quality of life and health care are becoming major considerations. The moral and ethical responsibilities to care for the elderly are problems that we face as health-care professionals from all disciplines. There is a need to become aware of geriatric foot and related problems, their assessment, and management, and how they affect clinical practice and the ability of our older citizens to remain vibrant and active members of their communities, and to live their lives with dignity.

The human foot is a marvel and has been called the ‘mirror of health’. The early recognition of diseases, disorders and systemic complications related to the foot and its related structures has much to do with all forms of prevention and management. A major component of the field of geriatric medicine and podogeriatrics is more than the ageing process itself. It includes clinical care, limb preservation, education, prevention, clinical management and the restoration of function. It also incorporates the social elements of life and the benevolent regard for each individual patient as paramount to society in general.

Geriatric clinical practice means more than just caring for older individuals. It implies a philosophy of compassion and understanding that must be incorporated into all health-care specialties that attempts to improve health and well being for patients with chronic diseases and/or disabilities throughout their lives.

*Foot Problems in Older People: Assessment and Management* critically and succinctly encompasses a wealth of information on the subject of geriatric foot care that is applicable and practical for all professions involved in the primary care of the older patient. Dr Menz has accomplished this task in a masterful fashion. One individual who has demonstrated a breadth of knowledge and understanding that provide great consistency in style and content has remarkably authored this monograph.

The text is extremely well organised, easy to read and inclusive of the basic primary elements of geriatric and related foot care. Each chapter provides a significant and comprehensive list of references. The manuscript provides a review of the epidemiology of foot problems in the elderly from a worldwide and international perspective, which is a first in current literature. Prevalence and risk factors for foot problems (including age, sex, obesity and co-morbidities) are related to the consequences of immobility, falls and quality of life.

This work includes practical discussions related to the aetiology, assessment and management of common foot disorders and diseases along with an emphasis on primary management and the prevention of complications. The text was designed to complement existing geriatric and specialty texts such as those in internal medicine, dermatology, foot surgery and foot orthopaedics to expand the concepts of care for older patients. Improving the quality of care to help ensure years without pain and to enhance the fulfillment of life are a demonstrated objective of this effort.

The physical changes related to assessment, the integument, keratotic changes, onychial disorders, the vascular system, neurosensory changes, musculoskeletal system including foot deformities of the digits, forefoot and rearfoot are well documented. Pain and arthritic changes have been properly presented. The segments dealing with conservative and surgical management enhance the primary care approach to patient care. The sections dealing with orthoses and footwear are focused on the older patient. The photographic illustrations and charts enhance the quality of the presentations and are augmented with a comprehensive list of references and bibliographic notations.

Clearly this text is a ‘labour of love’ and prepared by an individual who has devoted much of his career to care, research and education related to foot disorders in older patients. Dr Menz is to be
congratulated for this fine effort. He is a distinguished podiatrist, researcher, educator and the foremost scholar in the field of foot problems related to ageing in Australia. He is an established author, the Editor of the *Journal of Foot and Ankle Research*, and serves on several editorial peer review boards of gerontology and rehabilitation journals.

*Foot Problems in Older People: Assessment and Management* provides an excellent and current foundation for the podiatric student, the podiatry profession, geriatricians and related health-care professionals to understand and learn the principles and practice of providing foot care for geriatric patients and is a gem. This book will help elevate the standards of care for older patients, internationally, and belongs in all libraries that deal with the subjects of geriatric and gerontology.

Arthur E. Helfand
2008
During the 20th century most countries in the world underwent a remarkable demographic transition from high fertility and mortality rates to low fertility and mortality rates. Subsequently, we are now witnessing a substantial ageing of the population, with the most rapid population growth being observed in the oldest age groups – the oldest-old (85+ years) and centenarians (100+ years). In 2000 it was estimated that there were 180,000 people in the world aged over 100 years and current projections suggest that this figure could reach 1 million by 2030.

Population ageing poses significant challenges to health-care systems. While advances in health care have contributed to increased longevity, a direct consequence of this has been the corresponding increase in prevalence of chronic diseases such as cancer, cardiovascular disease, osteoarthritis and Alzheimer’s disease. Whether population ageing has resulted in longer periods of ill-health prior to death (referred to ‘expansion of morbidity’) or has delayed the age of onset of disability (‘compression of morbidity’) continues to be debated. However, irrespective of which scenario proves to be correct, it is clear that health-care workers need to be prepared for an increasingly older caseload for some time to come.

Management of foot problems is an important, yet often overlooked and undervalued component of geriatric health care. Even within podiatry, the profession entirely focused on the diagnosis and management of foot disorders, treatment of older people is perceived by many to be less interesting and fulfilling than other areas of practice. Subsequently, there is a paucity of literature pertaining to the management of the older foot. While generalist geriatrics textbooks often include a short section on foot disorders, to my knowledge, there has not been an entire textbook published on this topic since Arthur Helfand’s *Clinical Podogeriatrics* in 1981.

The objective of this book is to provide the reader with a comprehensive yet accessible review of the epidemiology, aetiology, assessment and management of foot conditions frequently observed in older people. While the book is primarily targeted towards a podiatry audience (particularly podiatry students), I hope that it will also be of interest to general medical practitioners, nurses, physiotherapists, orthotists, orthopaedic surgeons, rheumatologists and indeed any other health professional who cares for older people.

This book has 12 chapters, which can be broadly grouped into four sections: background information (Chs 1 and 2), assessment (Ch. 3), dermatological and vascular disorders (Chs 4–7), musculoskeletal disorders (Chs 8–10) and treatment approaches (Chs 11 and 12). Chapter 1 provides a detailed coverage of the epidemiology of foot problems in older people, outlining the findings of several large-scale studies of the prevalence, risk factors and consequences of foot problems. Chapter 2 discusses the effects of ageing on the integumentary, vascular, sensory and musculoskeletal structures of the foot and outlines the clinical implications of these changes. Chapter 3 is a long chapter that describes the assessment of the lower limb in older people, from the initial assessment interview and history taking through to diagnostic imaging. Chapters 4, 5, 6 and 7 outline the prevalence, aetiology, clinical presentation and treatment of keratotic disorders, other skin conditions, nail disorders and peripheral vascular disorders, respectively. Chapters 8, 9 and 10 are structured in a similar manner and focus on musculoskeletal disorders of the toes, forefoot and midfoot/rearfoot, respectively. Finally, Chapters 11 and 12 provide additional information about the role of footwear and foot orthoses in the management of these conditions.

In defining the size and scope of this book, it has been necessary to exclude or limit the coverage of some topic areas that are discussed in greater detail in existing texts. For example, while this book discusses common skin conditions affecting the foot, the reader is advised to supplement this information with a more general dermatology textbook. Similarly, foot surgery
and foot orthotic prescription are discussed in the context of the overall management of particular foot conditions, but details regarding individual techniques are beyond the scope of the book. In limiting the coverage of some of these topics, I do not wish to give the impression that they are less important. In fact, the opposite is actually the case; by referring readers to other sources, I hope to ensure that they are exposed to the appropriate level of detail that the topic deserves.

The book adopts an evidence-based approach to summarising the available literature, deferring to the conclusions of systematic reviews and randomised controlled trials where such sources of information are available. However, because our knowledge of the causes and best approaches to management of many foot conditions is incomplete, some areas of the book are more evidence-based than others. This is particularly evident in relation to many surgical procedures, the evidence of which is primarily derived from case-series studies. Hopefully, the recognition of the many gaps evident in the literature will act as a catalyst for some readers to initiate clinical research projects to help address these shortcomings.

I hope that this text will assist health-care professionals in optimising the quality of care for older people with foot problems, ensuring that the additional years gained through our increased life expectancy are as pain-free, active and fulfilling as possible.

Hylton B. Menz
2008
I am indebted to several people who have assisted in the completion of this book. First and foremost I would like to thank my wife, Elizabeth Barr, for her generous support and encouragement during the writing process, even while she toiled away on her PhD. I would also like to thank the many colleagues who provided me with access to their treasure trove of clinical photographs and allowed me to reproduce them in the book. Full photographic credits are provided throughout the text; however I would like to particularly thank Dr Karl Landorf, Lloyd Reed, Lesley Newcombe and Felicity Prentice.

Dr Karl Landorf, Ivan Bristow, Mark Gilheany and Nikki Frescos provided valuable suggestions on parts of the manuscript. Dr Shannon Munteanu assisted with the scanning of radiographs and Lucy Shaw assisted with preparing the clinical photographs. The editorial staff at Elsevier, including Robert Edwards, Veronika Krčilova and Rebecca Gleave, provided prompt and professional assistance from the initial development of the book proposal through to the final production of the book.

This book is dedicated to Dr Ramaswamy Ganapati, Director of the Bombay Leprosy Project, Mumbai, India, in recognition of his tireless and compassionate work in improving the lives of people affected by leprosy. I encourage all readers of this text to support the ongoing work of this not-for-profit organisation by making a donation at www.bombayleprosy.org.
Epidemiology of foot problems in older people

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PREVALENCE OF FOOT PROBLEMS

It has long been recognised that foot problems are highly prevalent in older people and have a significant detrimental impact on an older person’s independence and quality of life.1 However, the true epidemiology of foot problems in this population is difficult to ascertain for several reasons. Firstly, in contrast to most common conditions affecting older people, there is no consensus as to what actually constitutes a foot ‘problem’. This is largely due to the fact that a very broad spectrum of musculoskeletal, dermatological, vascular and neurological conditions may manifest in the foot, each requiring its own case definition. (In this chapter the terminology adopted by each individual study has been used.) Furthermore, the definition of a foot problem may also be broadened to include difficulties in maintaining basic foot hygiene (such as cutting toenails) or difficulty purchasing comfortable shoes.2

Secondly, while some prevalence studies rely on self-reporting of foot problems, others document the prevalence of foot problems based on clinical assessments. There are considerable discrepancies in prevalence estimates between these two approaches, with those based on self-report generally revealing significantly lower rates of foot problems. Whether older people under-report foot problems or clinicians over-report them is difficult to determine; however, there is some evidence that many older people consider foot problems to be an inevitable accompaniment of ageing3 and therefore do not consider reporting them as medical conditions in health surveys.4 Subsequently, comparisons of foot problem prevalence between
studies based on self-report and those involving clinical assessments are problematic.

The third major consideration when interpreting prevalence data on foot problems is the sample population. Most studies have been conducted on institutionalised older people, or on relatively small convenience samples in a range of clinical settings. While such studies are useful and often provide detailed information on a range of conditions, the prevalence estimates derived from such studies cannot be considered representative of the broader older population, because of inherent sampling bias. Very few well-designed epidemiological studies using representative random samples have been undertaken and, while large-scale national health surveys do provide representative data on medical conditions, few include detailed information on foot problems. Therefore, establishing the prevalence of foot problems in older people requires making a distinction between non-representative clinical studies that provide considerable detail in a small number of people and larger, representative epidemiological studies, which often lack clinical detail.

### STUDIES CONDUCTED IN AGED CARE FACILITIES AND INPATIENT SETTINGS

One of the earliest studies to examine the prevalence of foot problems was conducted on 1011 nursing home residents (300 men and 711 women, aged 60–90 years) in the USA. A podiatrist undertook a visual inspection of each resident and completed a simple checklist. Although no overall prevalence figures were provided, the most commonly observed conditions were corns (25%), hallux valgus (23%) and calluses (14%), with women exhibiting a higher prevalence of all foot conditions compared to men.

Subsequent studies in aged care facilities and hospitals have reported similar findings in relation to the most common foot problems but quite variable prevalence rates. Hsu et al.

hospital inpatients aged over 65 years (admitted to either a geriatric or orthopaedic ward) reported that 50% had at least one foot problem, the most common being calluses (40%), hallux valgus (20%) and lesser toe deformity (20%). Goniometric assessments also revealed that 70% had limited ankle motion, 40% had limited foot eversion and 15% had limited dorsiflexion of the first metatarsalphalangeal joint. Similar to the findings of Ebrahim et al., only a small number of patients (7%) reported foot discomfort.

Although it is difficult to compare these studies because of differences in study populations and assessment techniques, it is clear that hospital inpatients and older people residing in aged care facilities have a high prevalence of foot disorders. In all four studies, women demonstrated a higher prevalence of foot problems than men. The unexpected observation of a relatively low prevalence of foot symptoms in the two hospital-based studies highlights the aforementioned discrepancy in prevalence rates based on clinical assessments compared to self-report. However, the apparent discrepancy between observed foot conditions and reported symptoms in institutionalised older people may simply reflect the confounding effect of limited mobility, i.e. many of the older people in these studies may not have been physically active enough to develop foot symptoms.

### STUDIES CONDUCTED IN OUTPATIENT SETTINGS

Several studies involving the review of patient records from outpatient clinics have been conducted to examine the epidemiology of foot problems. The South Mountain Study conducted by Helfand et al. in 1968 involved assessments of 551 people aged over 65 years who were attending a rehabilitation centre in the USA. The most common foot conditions diagnosed by the attending podiatrists were hyperkeratosis (48%), dry skin (46%), thickened nails (42%) and hallux valgus (38%). Peripheral vascular conditions were also common, with 44% of patients having an absent posterior tibial artery pulse.

More recently, Plummer & Albert examined 308 new referrals to an outpatient foot care service in a USA health sciences centre over a 24-month period and found that the prevalence of foot abnormalities increased significantly with age, with 45% of patients aged 80–95 years exhibiting at least one foot abnormality. The key finding of this study was that older people without diabetes demonstrated a similar preva-
lence of inappropriate foot-care practices and ill-fitting footwear to younger patients with diabetes, suggesting that non-diabetic older people are at high risk for foot problems and should therefore receive similar foot-care screening and education to those with diabetes.

By far the most extensive outpatient study on the prevalence of foot problems is the Achilles Foot Screening Project. This study commenced in 1997 and involved clinical examination of the feet of people attending dermatologists or primary care physicians in Austria, Belgium, China, the Czech Republic, Germany, Greece, Hungary, Israel, Italy, Luxembourg, the Netherlands, Poland, Russia, Slovenia, South Africa, Sweden, Switzerland and the UK.11 The primary focus of this study was to determine the prevalence of fungal infections affecting the foot, although information was also collected on other foot conditions. Initial results from 13,695 people residing in six of the participating European countries12 revealed that a clinical diagnosis of a foot disorder was made in 58% of patients, with a much higher prevalence in those aged over 65 years (78%). The most commonly diagnosed conditions in older people were onychomycosis (45%), tinea pedis (29%), pes planus (28%), plantar corns and calluses (26%) and hammer toes (24%). A follow-up study involving 90,085 older patients across all the participating European countries13 reported that almost half had clinical evidence of fungal foot infection. Lower prevalence estimates in older people for tinea pedis (8%) and onychomycosis (6%) were reported in the Hong Kong arm of the study,14 although the sample size was considerably smaller (824 participants).

The main limitation with prevalence studies conducted in outpatient settings is that of sampling bias, in that the characteristics of the sample population studied reflects the geographical location of the clinical service and the method by which the service is administered (such as the eligibility criteria to access the service). In particular, inclusion in the Achilles Foot Screening Project is clearly biased towards older people who have pre-existing dermatological condition, as most assessments were performed in dermatology clinics. As such, the prevalence of fungal foot disease derived from this study is likely to be an overestimate.

### COMMUNITY-BASED STUDIES

The most accurate estimates of the prevalence of foot problems in the general older population are ideally provided by large-scale epidemiological studies involving random sampling of participants, using standardised definitions of various foot conditions. Unfortunately, very few such studies have been undertaken with a specific focus on foot problems. In many cases, foot problem prevalence data is derived from national health surveys, which may only include a single question about foot problems (e.g. do you have problems with your feet?), or from chronic pain prevalence studies, which request that the participant report the location of their pain. For the purpose of simplicity, foot problems or pain located in the foot are frequently combined with knee or hip disorders and documented as ‘lower extremity problems’. Therefore, in many studies it is difficult to delineate the prevalence of the foot problem itself. Despite these limitations, these studies do provide more precise estimates of foot problem prevalence than those conducted in clinical settings.

### Studies conducted in the USA

Several community-based prevalence studies involving clinical assessments have been conducted in the USA. The Keep Them Walking project, conducted in 1968, involved evaluations of 1366 older people attending a range of community centres and senior citizen clubs.15 An extremely high prevalence of clinically determined foot problems was reported (95%), with 74% of participants reporting foot pain. However, these figures need to be viewed with some caution, as no definitions of these foot complaints were provided and it is likely that the method of recruitment (talks to senior citizen clubs delivered by a podiatrist and mail-out leaflets about foot problems) skewed the sample towards those with foot problems. A subsequent study in 1998 using very similar methods16 reported a foot problem prevalence of 84% in 417 people, the most common conditions being foot pain (45%), corns (33%), calluses (26%) and hallux valgus (24%).

The Dunedin Program, which commenced in 1975 as a hypertension screening study, involved the administration of a questionnaire to 733 people aged over 65 in Dunedin, Florida, a popular retirement area in the USA.17 The results indicated that 60% of women and 32% of men were troubled by foot problems. The most commonly reported conditions were toenail problems (22%), calluses (20%), corns (16%), dry skin (15%) and bunions (13%). Women reported a higher prevalence of corns and bunions than men.
Similar figures for the prevalence of calluses (25%) and bunions (17%) were reported by Gould et al., who conducted a survey of foot problems by administering a questionnaire to 45,000 shoe stores across the USA.

The National Health Interview Survey (NHIS), undertaken by the USA Public Health Service, is a regular interviewer-administered survey of general health that includes questions on bunions, corns and calluses, and toenail problems. In 1990, the NHIS included an additional podiatry supplement with questions pertaining to foot infections, arthritis and orthopaedic conditions. The 1990 NHIS involved interviews with 119,631 people and reported a 31% prevalence of foot problems in respondents aged over 65 years. The most commonly reported problems were corns and calluses (11%), toenail problems (10%), bunions (5%) and foot infections (5%). Shortly after the NHIS, a smaller telephone survey of 1003 people conducted by a marketing company reported very similar findings: an overall 38% prevalence of foot problems in those aged over 65 and a similar breakdown of the most commonly reported conditions.

The Women’s Health and Aging Study is a longitudinal study of the causes of disability in 1002 women aged over 65 years. An analysis of baseline data revealed that 70% of the sample had bunions and 50% had hammer toes. A relatively small proportion of the sample reported ‘severe’ foot pain (14%), which was defined as pain lasting 1 month or longer and rated 7 or above on a scale from zero to 10. Interestingly, there was no association between the presence of foot deformities and severe foot pain.

The most recent community-based study to focus on foot problems in the USA was the Feet First study, a detailed investigation involving a random sample of 784 people aged over 65 in Springfield, Massachusetts. The location of the study was chosen because of its racial diversity in order to allow comparisons in the prevalence of foot problems to be made between non-Hispanic white, Puerto Rican and African Americans. Overall, the most common conditions were toenail disorders (75%), lesser toe deformities (60%), corns and calluses (58%) and bunions (37%). A summary of these findings according to sex is shown in Table 1.1. Toenail conditions, fungal infections, cracks and fissures, maceration between toes and ulcers or lacerations were more common in men, while bunions, corns and calluses, claw toes and high arches were more common in women.

### Table 1.1 Prevalence of foot problems (%) in older people in the USA according to sex

<table>
<thead>
<tr>
<th>Condition</th>
<th>Men</th>
<th>Women</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dermatological conditions</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thickened nails*</td>
<td>74.8</td>
<td>59.3</td>
<td>65.2</td>
</tr>
<tr>
<td>Elongated nails*</td>
<td>46.0</td>
<td>37.0</td>
<td>40.4</td>
</tr>
<tr>
<td>Ingrown nails</td>
<td>7.2</td>
<td>7.5</td>
<td>7.4</td>
</tr>
<tr>
<td>Corns/calluses†</td>
<td>45.7</td>
<td>65.9</td>
<td>58.2</td>
</tr>
<tr>
<td>Fungal infection</td>
<td>24.9</td>
<td>20.9</td>
<td>22.4</td>
</tr>
<tr>
<td>Cracks/fissures*</td>
<td>20.9</td>
<td>9.7</td>
<td>14.0</td>
</tr>
<tr>
<td>Maceration between toes*</td>
<td>5.7</td>
<td>1.6</td>
<td>3.2</td>
</tr>
<tr>
<td>Dry skin</td>
<td>15.3</td>
<td>12.8</td>
<td>13.7</td>
</tr>
<tr>
<td>Ulcers/lacerations*</td>
<td>7.9</td>
<td>1.9</td>
<td>4.2</td>
</tr>
<tr>
<td><strong>Orthopaedic conditions</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hammer toe</td>
<td>37.3</td>
<td>32.8</td>
<td>34.5</td>
</tr>
<tr>
<td>Mallet toe</td>
<td>29.4</td>
<td>35.9</td>
<td>33.4</td>
</tr>
<tr>
<td>Claw toe†</td>
<td>5.2</td>
<td>10.8</td>
<td>8.7</td>
</tr>
<tr>
<td>Bunionette</td>
<td>14.0</td>
<td>12.7</td>
<td>13.2</td>
</tr>
<tr>
<td>Overlapping toes</td>
<td>13.6</td>
<td>16.9</td>
<td>15.6</td>
</tr>
<tr>
<td>Missing toes</td>
<td>0.2</td>
<td>0.8</td>
<td>0.5</td>
</tr>
<tr>
<td>Bunion†</td>
<td>25.3</td>
<td>44.3</td>
<td>37.1</td>
</tr>
<tr>
<td>Hammer toe (great toe)</td>
<td>0.8</td>
<td>0.6</td>
<td>0.7</td>
</tr>
<tr>
<td>Cock-up hallux</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
</tr>
<tr>
<td>Flat feet</td>
<td>17.2</td>
<td>20.1</td>
<td>19.0</td>
</tr>
<tr>
<td>High arch†</td>
<td>2.4</td>
<td>7.0</td>
<td>5.2</td>
</tr>
<tr>
<td><strong>Pain and tenderness</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ankle joint pain</td>
<td>14.1</td>
<td>15.3</td>
<td>14.9</td>
</tr>
<tr>
<td>Tenderness to palpation (any site)</td>
<td>26.0</td>
<td>33.9</td>
<td>30.9</td>
</tr>
<tr>
<td>Tenderness: metatarsophalangeal joints</td>
<td>17.9</td>
<td>21.7</td>
<td>20.2</td>
</tr>
<tr>
<td>Tenderness: interstitial spaces</td>
<td>15.2</td>
<td>17.8</td>
<td>16.8</td>
</tr>
<tr>
<td>Tenderness: plantar fascia</td>
<td>6.4</td>
<td>7.2</td>
<td>6.9</td>
</tr>
<tr>
<td>Tenderness: plantar heel pad</td>
<td>3.9</td>
<td>4.3</td>
<td>4.2</td>
</tr>
<tr>
<td>Tenderness: medial malleolus</td>
<td>9.0</td>
<td>13.2</td>
<td>11.6</td>
</tr>
</tbody>
</table>

*men > women (p < 0.05). †women > men (p < 0.05)

Studies conducted in the UK

Several community-based studies of foot problems have been conducted in the UK for the purpose of determining foot health service provision needs in the National Health Service. In 1986, the Department of Health and Social Security funded a study involving
a random sample of 543 people aged over 65 years.\textsuperscript{23} Initially, participants completed a questionnaire that asked whether they had a foot problem, and then 70% of the sample was assessed by a chiropodist. Half of the sample (52%) reported that they had foot problems, while foot conditions were diagnosed in 84% of the sample by the chiropodists. The most common problems reported were similar to previous studies (nail problems, corns and bunions), although the clinical assessments also revealed a high prevalence of orthopaedic disorders such as hammer toes and flat feet.

Subsequent studies have largely confirmed these findings, particularly in regard to the very high prevalence of foot conditions reported when foot care specialists undertake the assessments. A study of 999 community-dwelling older people by Elton & Sanderson\textsuperscript{24} found that 71% were considered to have a foot problem by the chiropodist, and White and Mulley\textsuperscript{25} reported that, of 96 people aged over 80 years living in their own homes, only six were considered to have normal, healthy feet. However, consistent with studies in clinical populations, a much smaller proportion reported symptoms (30%). Wessex Feet, a foot health survey of 700 people (including 200 aged over 65 years), reported a prevalence of ‘foot problems’ of 62%, with calluses (42%), nail problems (41%), corns (30%) and hallux valgus (27%) being the most commonly reported conditions in the older group.

More recently, four studies involving random samples of community-dwelling older people in the UK have reported prevalence data on foot disorders. The Clifton Assessment Procedure for the Elderly study\textsuperscript{27} in Northern Ireland involved a questionnaire of 248 people aged over 65 years. Difficulty cutting toenails was the most commonly reported problem (96%), followed by corns (48%), hard skin (36%) and hallux valgus (12%). A larger community study conducted in Wales\textsuperscript{28} involving clinical examinations of 792 people aged over 60 years reported that 53% had three or more foot problems, the most common being lesser toe deformities, corns and calluses. Finally, the Cheshire Foot Pain and Disability Survey\textsuperscript{29} of 4780 people aged 18–80 years reported a relatively low prevalence of foot pain in those aged over 65 (approximately 13%); however, the case definition of foot pain required that participants have current foot pain, pain lasting for at least 1 month, and have documented at least one disability item on the Manchester Foot Pain and Disability Index.\textsuperscript{30} As such, the figure reported is likely to represent more severe foot pain than other surveys.

### Studies conducted in other countries

Although the majority of community-based studies have been conducted in the USA or UK, several smaller studies have been undertaken in Australia and in some European countries.

In Australia, a mail-out questionnaire study\textsuperscript{4} conducted on 128 older people reported that 45% of men and 59% of women suffered from painful feet, mostly affecting the toes. Other commonly reported problems were nail disorders, corns and bunions. The Health Status of Older People Project conducted in 1994 was a community-based study of 1000 people aged over 65, and found a 30% prevalence of self-reported ‘problems with feet or legs’\textsuperscript{31} A more recent prevalence study of lower extremity pain in 1486 older women reported that 34% experienced foot pain.\textsuperscript{32}

Two community-based studies in Italy and the Netherlands reported similar findings in relation to the prevalence of self-reported foot pain. Benvenuti et al\textsuperscript{33} studied 459 people aged over 65 living in a small Italian town and reported that at least one foot symptom or sign was recorded in 83% of the sample, with the most common conditions being calluses or corns (65%), thickened nails (30%) and hallux deformities (21%). Foot pain ‘when standing’ was reported by 22% of the sample. A larger study of 7200 people aged over 65 conducted in the Netherlands\textsuperscript{34} reported a similar prevalence of 20% for self-reported foot problems of more than four weeks’ duration.

## Risk Factors for Foot Problems

Foot conditions in older people are generally chronic and have taken many years to develop, so it is unlikely that there will ever be a prospective, longitudinal study to determine why some people develop foot problems and others do not. Nevertheless, several of the previously discussed prevalence studies have also evaluated the role of age, sex and co-morbidities in the development of foot problems, and such cross-sectional data provides useful insights into which factors may influence the development of foot symptoms.
The most obvious risk factor for the development of foot problems is advancing age, as prevalence studies involving participants across a wide age range have consistently found that older people have much higher rates of foot problems. However, there is some evidence of a non-linear relationship, in that the prevalence seems to increase until the age of approximately 65 years and decline thereafter (Fig. 1.1). This is probably because of the confounding influence of physical activity. As discussed previously in relation to the lower rates of foot symptoms reported by institutionalised older people, it could be that the development of foot symptoms requires a certain level of weightbearing activity, so even older people with severely deformed feet may not develop symptoms if they lead a largely sedentary lifestyle.

**SEX**

Sex has a clear influence on foot problems, with several studies indicating that women have a higher prevalence of foot conditions, particularly hallux valgus, corns and calluses, and are more likely to report foot pain. However, the Feet First study, which included a wider array of foot conditions than most prevalence studies, found that, although women were more likely to exhibit hallux valgus, corns and calluses, other conditions (nail conditions, fungal infections and ulcers) were more prevalent in men. The most likely explanation for the higher prevalence of foot problems in women is the wearing of shoes with an elevated heel and narrow toe box. Heel elevation increases the pressure borne by the metatarsal heads, and it has previously been demonstrated that older people who wear shoes that are too narrow or too short are more likely to have corns, lesser toe deformities, hallux valgus and foot pain. However, the higher prevalence of foot pain may also reflect sex differences in pain tolerance in general, since women are more likely to report musculoskeletal pain and pain interference at other body regions.

**OBESITY**

Several studies have reported an association between body mass index (BMI) and foot pain in older people, although there is little evidence that older people with overweight or obesity have a higher prevalence of structural foot disorders. A plausible explanation for the link between obesity and foot problems can be derived from plantar pressure studies. Several investigations have assessed the loading patterns of the foot in obese and non-obese people and have demonstrated significant increases in force and pressure under the foot when walking, particularly under the midfoot and metatarsal heads. Over time, it is likely that these elevated forces will overload plantar tissues and lead to the development of conditions such as metatarsalgia and plantar heel pain.

Further evidence to support a causal relationship between obesity and foot problems can be derived from a recent study of 48 obese patients undergoing bariatric surgery. Prior to surgery, all patients reported musculoskeletal complaints, with 50% reporting musculoskeletal foot pain. 6–12 months following surgery (which resulted in an average weight loss of 41 kg), only 23% of patients reported musculoskeletal symptoms and only 4% reported foot pain.

**CO-MORBIDITIES**

A wide range of co-morbidities are associated with the development of foot problems, such as diabetes, rheumatoid arthritis, stroke and systemic sclerosis. These associations largely reflect the direct consequences of the specific systemic disease process on the vascular, neurological, integumentary and musculoskeletal structures within the foot. However, foot problems are more common in older people with multiple chronic diseases or pain in other body regions and several recent reports have sug-
gested that chronic foot pain in older people may be part of a generalised form of osteoarthritis or systemic pain syndrome. Leveille et al found that older women with foot pain were more likely to have ankle oedema and osteoarthritis affecting the knees or hands. Similarly, participants with foot pain in the Cheshire Foot Pain and Disability Survey were more likely to report pain in the shoulder, axial skeleton, hip, knee and hands, and two recent studies reported that while few structural foot conditions were associated with foot pain in older people, those with foot pain were more likely to report osteoarthritis or pain in the spine, hips, hands or wrists.

The role of psychological factors in the development of foot pain has been suspected for some time and two studies have reported that older people with foot problems are more likely to report depression. Although it is possible that the depression is a consequence of foot pain rather than a causative factor, there is emerging evidence from studies of chronic generalised musculoskeletal pain that various forms of psychological distress may precede the development of symptoms. Furthermore, it has been shown that people with severe mental illness (including schizophrenia, major depression and bipolar disorder) have a significantly higher prevalence of foot pain than the general population. Prospective studies are required to confirm whether a cause and effect relationship between psychological factors and foot pain does indeed exist.

INCOME, EDUCATION AND ETHNICITY

Despite the general consensus that health status is strongly linked to sociodemographic factors, the role of education and income in the prevalence of foot problems in older people is equivocal. While some studies have reported that older people with foot problems have a lower level of income, others have failed to find such an association. Similarly, lower levels of education have been found to be associated with foot problems in some studies but not others. These discrepancies are likely to reflect differences in how income levels are defined, differences in educational systems between countries and variability in adjustment for confounders in the statistical models.

The influence of ethnicity on foot problem prevalence has received little attention in the literature. Two community-based studies in the USA have found that African Americans report a higher prevalence of foot problems than non-African Americans. However, only one study has focused on ethnic differences in clinically assessed foot problems. The Feet First study specifically selected a multi-ethnic community in Springfield, Massachusetts (including Puerto Rican, non-Hispanic white and African American residents) to investigate ethnic differences in foot problems. After adjusting for sex, Puerto Ricans were far less likely to have toe deformities and sensory loss than non-Hispanic whites or African Americans, while bunions and ankle oedema were more common in African Americans. The prevalence of pain was also influenced by ethnicity, with Puerto Ricans more likely to report tenderness to palpation at any site on the foot. Overall, ethnicity influenced foot problem prevalence more than education levels.

As with many other health conditions, ethnic differences in the prevalence of foot problems are likely to reflect a range of historical, cultural and socioeconomic factors that influence lifestyle and access to health care, rather than genetic susceptibility. Furthermore, the racial groupings used in epidemiological studies are inconsistent, which makes direct comparisons between studies extremely difficult.

CONSEQUENCES OF FOOT PROBLEMS

MOBILITY

The foot provides the only direct source of contact with the supporting surface during weightbearing activities, so it reasonable to expect that foot problems could have a detrimental effect on mobility in older people. Several investigators have directly questioned older people as to whether their foot problems interfered with daily activities. White & Mulley interviewed 106 people aged over 80 years and reported that 34% of those with foot pain felt that their foot pain prevented them from walking. Similarly, studies of community dwelling people aged over 65 years by Black & Hale and Cartwright & Henderson found that many older people attributed their limited activity to foot problems. Significant associations between the presence of foot problems and foot-related functional limitation, self-reported disability and inability to perform activities of daily living (such as housework, shopping and cooking) have also been reported.

Other studies have explored this relationship by conducting physical assessments in people with and
without foot problems. An evaluation of gait patterns in 459 older people by Benvenuti et al63 revealed that those with foot pain required a greater number of steps to walk 3 m than those free of foot problems. A similar study of 1002 older women21 found that those with chronic and severe foot pain walked more slowly and took longer to rise from a chair, while Barr et al31 found that self-reported foot or leg problems were significantly associated with impaired performance on the Timed Get Up and Go test (a timed mobility test that involves rising from a chair and walking 6 m). Finally, a recent study found that an overall measure of foot impairment was significantly associated with impaired performance in tests of balance (including postural sway and leaning tests) and functional ability (including stair walking and rising from a chair).60

II FALLOWS AND INJURIES

The association between foot problems and falls has been suspected for some time. In 1958, DeLargy61 hypothesised that decreased activity associated with foot problems in older people could lead to the development of muscle weakness, thereby predisposing to falls. In contrast, Helfand62 argued that painful lesions and structural foot deformities could directly lead to a fall by detrimentally altering the foot’s functional base of support. As discussed in the previous section, there is now sound evidence that various foot characteristics are significant independent predictors of balance and functional ability, and there is emerging evidence that foot problems are also a risk factor for falls.

Studies of falls risk factors can be divided into two categories: retrospective studies, in which older people’s history of falling (usually in the past 12 months) is documented and comparisons made between fallers and non-fallers; and prospective studies, in which foot characteristics are measured at baseline and the incidence of falls is determined by following participants over a 12 month period. Six retrospective studies have shown that older people who suffer from foot problems are more likely to have fallen in the previous 12 months.31,60,63–66 However, retrospective studies are limited because of the questionable accuracy of recall of falls by older people62 and difficulties in determining a causal relationship.

Five prospective studies have now confirmed that foot problems are a falls risk factor. A study of 100 men aged 65–85 years by Gabell et al68 reported that undefined ‘foot problems’ was associated with a fourfold increased risk of falling. Tinetti et al99 found that the presence of a ‘serious foot problem’ (defined as a moderate to severe bunion, toe deformity, ulcer or deformed nail) doubled the risk of falling in 336 people aged over 75 years after adjusting for sociodemographic characteristics, psychological factors and medication use. A prospective study of 979 people aged over 70 years in Finland found that older people with bunions were twice as likely to fall than those without.70 Follow-up results from the Women’s Health and Aging Study of 1002 women aged over 65 years found that foot pain was the only site of pain that was significantly associated with falls.71

The most recent prospective study of foot problems and falls72 assessed a wide range of foot and ankle characteristics (including foot posture, range of motion, deformity, lesions, tactile sensation, toe strength and pain) in 175 retirement village residents. During the 12 month follow-up period, 71 (41%) reported falling and, compared to those who did not fall, fallers demonstrated decreased ankle flexibility, more severe hallux valgus deformity, decreased plantar tactile sensitivity, decreased toe plantarflexor strength and a higher prevalence of disabling foot pain.

In addition to falls, a recent study has suggested that foot problems may also increase the risk of automobile accidents in older people. A prospective cohort study of 283 people aged over 72 years by Marottoli et al73 found that those with three or more foot problems (including nail problems, calluses, bunions and hammertoes) were twice as likely to have been involved in an automobile accident during the 12 month follow-up period. This association remained significant after adjusting for several possible confounding variables related to physical performance, suggesting that foot problems may increase the risk of automobile accidents by interfering with the ability to manoeuvre between the accelerator and brake pedals.

II HEALTH-RELATED QUALITY OF LIFE

Quality of life in older people is strongly associated with the ability to independently undertake physical tasks free of pain and, as such, musculoskeletal conditions are a major cause of disability and reduced quality of life in this population. Several recent studies have indicated that foot problems have a detrimental impact on self-reported measures of physical, mental and social function. Using the Medical Outcomes Study Short Form 36 (SF-36) questionnaire in a com-
munity sample of 1486 women aged over 70 years, Chen et al. found that the presence of foot pain was a significant determinant of both the physical component and mental component summary scores of the SF-36. Similarly, a study of 301 community-dwelling older people by Menz et al. reported that a continuous measure of foot impairment (the Manchester Foot Pain and Disability Index) was significantly correlated with the SF-36 general health and mental health subscales. Finally, two studies have indicated that older people presenting for hallux valgus surgery exhibit significantly worse SF-36 bodily pain and physical function scores compared with the general population.

**SUMMARY**

Foot problems are reported by at least one in three community-dwelling older people, with higher prevalence rates observed in institutional and clinical settings. The most common foot conditions in older people are nail disorders, corns and calluses, and toe deformities (including hallux valgus and lesser toe deformities). Risk factors for foot problems include age, female sex, obesity and multiple chronic diseases; however, the role of socioeconomic factors and ethnicity is unclear. Foot problems have a significant detrimental effect on mobility and quality of life in older people.

**References**


Physiological changes in the ageing foot

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The foot undergoes significant structural and functional changes with advancing age. While many of these changes merely reflect the physiological alterations in tissues elsewhere in the body, some changes are more pronounced than those that occur in other body regions, while others are unique to the highly specialised loadbearing structures of the foot. Indeed, it has been argued that careful assessment of the older foot can provide useful clinical insights into systemic conditions yet to be clearly manifested elsewhere. The following chapter reviews the body of literature pertaining to age-related changes of the foot in relation to the integumentary system, the soft tissue structures, the peripheral vascular and sensory systems, the skeletal system and the muscular system, and discusses the functional implications of these changes.

INTEGUMENTARY SYSTEM

The integumentary system consists of the skin, nails and subcutaneous tissues. The primary functions of this system are to provide a barrier between the body and its surrounding environment, to provide sensory information and to assist in the regulation of body temperature. Normal ageing is known to affect the structure and function of each of the components of the integumentary system, which often manifest as characteristic changes to the appearance of the foot. These changes are summarised in Table 2.1 and are described in more detail in the following section.
PHYSIOLOGICAL CHANGES IN THE AGEING FOOT

Table 2.1 Summary of major age-related physiological changes to the integumentary system

<table>
<thead>
<tr>
<th>Age-related changes</th>
<th>Implications</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Skin</strong></td>
<td></td>
</tr>
<tr>
<td>↓ production and turnover of keratinocytes</td>
<td>↑ dryness of skin → fissuring and hyperkeratosis</td>
</tr>
<tr>
<td>↓ density of sweat glands</td>
<td>↑ risk of infection</td>
</tr>
<tr>
<td>↓ number of Langerhans cells</td>
<td>↓ wound healing</td>
</tr>
<tr>
<td>↓ number of dermal collagen and elastin fibres</td>
<td>↑ wound dehiscence</td>
</tr>
<tr>
<td>↑ thickness and stiffness of dermal collagen fibres</td>
<td>↑ bruising</td>
</tr>
<tr>
<td>↓ capillary loops in papillary dermis</td>
<td></td>
</tr>
<tr>
<td><strong>Nails</strong></td>
<td></td>
</tr>
<tr>
<td>↓ nail growth rate (up to 50% reduction)</td>
<td>↑ time required to treat nail infections</td>
</tr>
<tr>
<td>↑ nail plate thickness</td>
<td>↑ rate of re-infection</td>
</tr>
<tr>
<td><strong>Plantar soft tissues</strong></td>
<td></td>
</tr>
<tr>
<td>Distortion and rupture of septa</td>
<td>↑ peak pressures under forefoot → metatarsalgia</td>
</tr>
<tr>
<td>↓ compressibility</td>
<td>Development of plantar heel pain</td>
</tr>
<tr>
<td>↑ stiffness</td>
<td></td>
</tr>
<tr>
<td>↑ energy dissipation</td>
<td></td>
</tr>
</tbody>
</table>

EPIDERMIS AND DERMIS

The skin of the sole of the foot has several unique features. Most notably, plantar skin is hairless and, although it contains a high density of eccrine sweat glands, it has no sebaceous glands.3 The plantar epidermis is considerably thicker (approximately 1.5 mm thick, compared to 0.1 mm in other regions of the body) and demonstrates a pattern of ridges that assist in generating sufficient friction when standing and walking barefoot. The plantar dermis is approximately 3 mm thick and is penetrated by adipose tissue, which provides resilience to shear stresses.3,4 Plantar skin is also highly adaptable, as evidenced by the considerably thicker epidermis and dermis observed in people who do not wear shoes.6 Because of this adaptability, it is sometimes difficult to delineate age-related changes from the effects of weightbearing activity and footwear.

Advancing age is associated with several significant changes to the structure and function of the skin at both the epidermal and dermal levels.5,6,9 The thickness of the epidermis does not change appreciably with age;10 however, the dermal–epidermal junction becomes flattened, which may give the impression of atrophy.11 In the foot, there may be an increase in epidermal thickness due to thickening of the stratum corneum associated with plantar calluses.12 The shape and size of epidermal keratinocytes becomes more variable, and the rate of production and turnover of keratinocytes may reduce to only 50% of that of a young person.13 Because of this delay in turnover time, the moisture content of keratinocytes is reduced, which, combined with the reduction in sweat gland density,14 contributes to the dry, scaly appearance of elderly skin.7,8 Langerhans cells, which play an important role in the immune function of the epidermis, decrease dramatically with age,15 resulting in a reduced rate of sensitisation to microorganisms.16

In contrast to the epidermis, the dermis undergoes a significant reduction in thickness due to a marked loss of collagen fibres.17 The collagen fibres that remain become thicker and stiffer and undergo a haphazard cross-linking process.7,18 Elastin fibres, which provide the skin with its elasticity, decrease in number and become fragmented.19,20 These processes alter the mechanical properties of the skin, leading to increased fragility and loss of elastic recoil. Dermal macrophages and mast cells, which provide the second line of immune defence after epidermal Langerhans cells, reduce in number with advancing age, lowering the speed and intensity of the inflammatory response to infection.16

Another factor that contributes to the impaired inflammatory response in older people is the age-related decline in cutaneous microvascular function. Older people exhibit a significant reduction in the number of capillary loops in the papillary dermis, increased porosity of endothelial cells and a thickened
basement membrane, all of which contribute to a less efficient superficial blood supply.\textsuperscript{13,21–23} It has been demonstrated that a 70-year-old may have up to 40% less blood supply to the skin than a 20-year-old,\textsuperscript{24} and these age-related changes appear to be particularly pronounced in the lower limb. One of the most obvious manifestations of this change is a progressive reduction in skin surface temperature extending distally from the groin.\textsuperscript{25}

\section*{NAILS}

Nails are comprised primarily of keratin produced by the nail matrix, with a small contribution from the underlying nail bed.\textsuperscript{26} Compared to fingernails, toenails are thicker (1.65 versus 0.60 mm) and have a slower linear growth rate (1 mm/month versus 3 mm/month).\textsuperscript{27,28} With advancing age, the rate of growth of the nails decreases by up to 50%,\textsuperscript{29,30} because of both a reduction in the turnover rate of keratinocytes and a reduction in size of the nail matrix itself. This process is particularly pronounced in toenails, possibly because of the greater age-related decline in blood supply to the feet compared to the hands.\textsuperscript{28}

In addition to decreased rate of growth, the chemical composition, histology and structure and appearance of the nail plate changes with age. Older nails exhibit an increase in calcium and reduction in iron content, increased size of keratinocytes and degeneration of elastic tissues beneath the nail bed.\textsuperscript{28} The formation of longitudinal grooves and an overall increase in thickness (onychauxis), often leads to a marked loss of translucency,\textsuperscript{2,27} while periods of arrested growth due to periods of systemic illness may also manifest as transverse ridges known as Beau’s lines.\textsuperscript{27} These changes are exacerbated by the presence of arterial insufficiency and low-level chronic trauma from ill-fitting footwear.\textsuperscript{27,28}

\section*{FUNCTIONAL IMPLICATIONS}

The physiological changes in the integumentary system that occur with ageing have important functional implications. As stated previously, the decreased water content of keratinocytes and decreased density of eccrine glands leads to an overall drying of the skin, which predisposes to the development of hyperkeratosis and fissuring. The reduction in epidermal and dermal immune function increases the risk of infection\textsuperscript{31} and the reduced rate of epidermal turnover may increase the time required to successfully treat these infections.\textsuperscript{2}

Wound healing is significantly delayed in older people, because of both a reduction in wound contraction (a direct result of collagen cross-linking and diminished elastin content of the dermis) and a reduced rate of epithelialisation and angiogenesis.\textsuperscript{32–34} Even if a wound successfully heals, the tensile strength at the wound site is diminished, which increases the likelihood of dehiscence. Subsequently, wounds in older people often require much longer periods of treatment and frequently recur. Bruising is also more likely to occur because of the decreased integrity of superficial blood vessels leading to leakage of red blood cells into the papillary dermis.\textsuperscript{2}

Age-related changes in the structure and function of the nail have important implications for the management of fungal nail infections (onychomycosis), one of the most common foot problems in older people.\textsuperscript{35} Because of the reduction in nail growth rate and subsequent thickening of the nail plate, treatment of onychomycosis with either oral or topical agents may take considerably longer in older people and the possibility of reinfection is much higher.\textsuperscript{36}

\section*{PLANTAR SOFT TISSUES}

The sole of the foot has highly specialised soft tissue structures in the heel and metatarsal head regions that are designed to absorb impact forces associated with weightbearing activities. Ageing is known to influence both the structure and function of these tissues and, although the literature is inconsistent, there is emerging evidence that these changes may be associated with the development of symptoms.

\subsection*{Metatarsal pads}

The plantar tissues of the forefoot serve numerous functions, including anchoring the skin to the underlying bony architecture of the foot, protecting underlying flexor tendons, blood vessels and nerves, and attenuating both vertical and shear forces applied during gait.\textsuperscript{37} The latter function is achieved by specialised pads of fat cells under each metatarsal head confined by retinacula extending from the dermis to the sides of each flexor tendon sheath.\textsuperscript{4} The metatarsal pads progressively decrease in thickness from the first to fifth metatarsal heads\textsuperscript{38–40} and undergo compression of 10–15% when standing\textsuperscript{40} and up to 46% during gait.\textsuperscript{41}
Although atrophy of metatarsal padding is frequently observed in older people, no studies have confirmed this finding using imaging techniques. Furthermore, no histological studies have been undertaken to ascertain whether ageing is associated with a breakdown of the connective tissues of the plantar forefoot. However, comparisons of the mechanical properties of metatarsal pads in young and older people by Hsu et al and Wang et al have demonstrated that older pads demonstrate greater stiffness, dissipate more energy when compressed and are slower to recover after the load is removed, all of which are likely to impair the ability of the forefoot to attenuate forces when walking.

Heel pad

The heel pad consists of a 13–21 mm thick layer of connective tissue, the deepest portion of which is firmly adhered to the plantar periosteum of the calcaneus by a series of dense fibrous septa containing closely packed fat cells. In response to loading, these fat cells flow within the individual chambers, and it is this mechanism, along with the elastic properties of the septa themselves, that provides the heel pad with its shock attenuation capability.

Evaluations of cadaver heel pads indicate that, with advancing age, the collagen fibres within the septa increase in number and size and appear more fragmented. As a result, the septa may become distorted and rupture, leading to a leakage of fat cells. However, this process does not lead to an overall decrease in the unloaded thickness of the heel pad; indeed, there is some evidence that older heel pads are slightly thicker than those of younger people. Rather, the functionally important age-related differences relate to how the heel pad responds to applied loads. Kinoshita et al used a drop-testing apparatus that applied a 5 kg mass to the heels of 10 young and 20 older people at two impact velocities. At the faster impact velocity (0.94 m/s), the older heel pads demonstrated less deformation and greater energy dissipation. In a study using ultrasound measurements of the heel pad in response to vertical loading, Hsu et al found that, while the unloaded heel pads of older people were slightly thicker, they demonstrated less compressibility than the younger subjects when a 3 kg load was applied. Evaluation of stress–strain curves indicated that older subjects’ heel pads were also slightly stiffer and dissipated more energy.

Functional implications

The functional implications of the changes in plantar soft tissues associated with ageing are unclear. While atrophy of the metatarsal fat pads has been suggested to be a contributing factor to the development of forefoot pain, a recent study using ultrasound measurements found no differences in the thickness of metatarsal pads in those with and without metatarsalgia. However, it is likely that the mechanical properties of the fat pads are more relevant than their thickness, as it has been shown that the peak pressure under the metatarsal heads during gait is greater in people with forefoot symptoms. Similarly, while research findings related to the role of heel pad thickness in the development of heel pain are equivocal, it appears that painful heel pads are less compressible and dissipate more energy. Further studies utilising dynamic measurements of plantar soft tissues are therefore required to confirm the suspected association between ageing soft tissues and foot pain.

PERIPHERAL VASCULAR SYSTEM

ARTERIES

The arterial wall consists of three layers. The innermost layer, the intima, is composed of endothelial cells, which provide a smooth surface for the passage of blood, supported by a meshwork of collagen and elastin fibres. The middle layer (media) of large arteries consists mostly of elastin and provides vessels with the ability to expand and contract in response to changes in blood flow volume. In contrast, the media of small arteries is largely made up of smooth muscle. The outermost layer (adventitia) is primarily loose connective tissue, which assists in flexibly anchoring the vessel to surrounding structures.

A summary of age-related changes in the peripheral vascular system is provided in Table 2. Normal ageing does not appear to affect the structure or function of the adventitia; however, considerable changes take place in the intima of all vessels and the media of large arteries. For reasons that are still unclear, the size and shape of endothelial cells become more irregular, and the overall thickness of the intima and media increases as a result of collagen cross-linking and invasion of smooth muscle cells. Elastin fibres in the media of large arteries break down and stiffen,
ing in a reduction in elastic recoil, a reduction in overall flow and an elevation in blood pressure.57 These age-related changes appear to be most pronounced in the lower limb. For example, pulse transmission times (a measure of arterial stiffness) decrease by 1.6 ms/year in the toes compared to 0.6 ms/year in the fingers58 and vasodilation in response to occlusion decreases by 7% per decade in the calf compared to 4% per decade in the forearm.59

### CAPILLARIES

Capillaries are often less than 1 mm in length and consist of a single layer of endothelial cells supported by a basement membrane. The primary role of capillaries is the exchange of oxygen from red blood cells to surrounding tissues and absorption of waste material. With advancing age, capillaries become even narrower and their porous walls increase in thickness, because of basement membrane thickening and collagen deposition.60 As a result of these changes, ageing is associated with an overall reduction in capillary blood flow, particularly in the lower limb.51,62

### VEINS

Veins have the same basic structure as small arteries but are larger in diameter and exhibit considerably thinner walls. Relatively little is known about the effects of age on the microstructure of veins and no studies have directly evaluated the effect of age on structure and function of foot veins. However, the diameter of the femoral veins has been shown to decrease slightly from the age of 60 years and the velocity of blood flow within them steadily declines from the age of 50 years.65 Advancing age is also significantly associated with perforator vein incompetence,64 which may result from the accumulation of collagen fibres around valves.

### FUNCTIONAL IMPLICATIONS

The overall decline in peripheral vascular function in older people clearly manifests in the foot. Even in the absence of overt vascular disease, many older people complain of cold feet and exhibit dry, flaky skin, particularly on the dorsum of the foot and the toes. As stated in the section on the integumentary system, peripheral vascular changes contribute to delayed wound healing and increased risk of infection. Furthermore, although the development of peripheral arterial disease is multifactorial, age itself has been shown to be an independent risk factor, with an approximate twofold increase in risk for every 10-year increase in age.65 Age is also an independent risk factor for conditions associated with venous insufficiency, such as varicose veins66,67 and venous ulcers,68 which commonly affect the foot and ankle.

### PERIPHERAL SENSORY SYSTEM

The key components of the peripheral sensory system are the sensory neurons, which consist of a nerve cell body, branch-like extensions called dendrites and an elongated axon that extends from the nerve cell body, and a range of sensory receptors, which are located in the skin and detect a range of stimuli, including vibration, pressure and temperature.69 In particular, the glabrous skin on the sole of the foot contains large populations of mechanoreceptors capable of detecting the site, velocity and acceleration of mechanical stimuli.69–71

A summary of age-related changes in the peripheral sensory system is provided in Table 2.3. With advancing age, there is a generalised decline in the size and number of axons, and the myelin sheaths surrounding the axons undergo significant deterioration, leading to a reduction in nerve conduction velocity.72 Merkel discs and free nerve endings are not affected by age; however, Meissner and Pacinian corpuscles considerably reduce in density and the receptors that remain exhibit a number of morphological alterations.73 As a
result of changes in receptor structure and function, ageing is associated with significant reductions in tactile sensitivity,74–77 spatial acuity78–81 and vibration sense,74,77,82–85 and these changes are particularly pronounced in the lower limb compared to the upper limb.79,82,86

Proprioception (the ability to detect the position of body parts) and kinaesthesia (the ability to detect movement of body parts) rely partly on skin receptors but also on Golgi tendon organs and receptors in muscle spindles.87 As with other mechanoreceptive abilities, ageing is associated with significant decline in proprioception and kinaesthesia in the sagittal plane of the knee76,88–91 and the sagittal92–95 and frontal plane96 of the ankle.

### FUNCTIONAL IMPLICATIONS

When standing and walking, the sole of the foot provides the only direct contact with the ground and therefore provides important sensory information about the supporting surface.97 Furthermore, ankle proprioception plays an important role in maintaining balance when walking on irregular terrain. Subsequently, age-related changes in peripheral sensation are associated with deficits in balance98–103 and walking speed,104,105 and reduced peripheral sensation is an important risk factor for falls.106,107 Loss of plantar sensation in older people may also result in pressure from ill-fitting footwear or foreign bodies within the shoe being undetected, leading to tissue damage and ulceration.108

### SKELETAL SYSTEM

#### BONE

Bone cells produce two types of tissue: cortical bone, which consists of long tubes of bone matrix (called osteons) forming the outer layer of the bone, and trabecular bone, an irregular matrix that forms the central core of the bone. Cortical bone comprises approximately 90% of the skeleton and is found primarily in long bones. Both types of bone are in a continuous process of remodelling, because of a coupling between bone formation by osteoblasts and bone resorption by osteoclasts. This process enables bone to respond to changing mechanical and metabolic demands.109

A summary of age-related changes in the skeletal system is provided in Table 2.4. Age-related changes in the physiology and biochemistry of bone cells are complex and only partly understood; however, it is thought that ageing primarily affects the structure and function of bone marrow, from which cellular precursors to osteoblasts and osteoclasts are formed. This results in reduced osteoblastic activity, and subsequently the amount of bone formed is not equivalent to the amount of bone resorbed.110 Bone mass therefore undergoes a characteristic trajectory throughout the lifespan, with steady increases in bone density throughout adolescence, a plateau between the third and fifth decade and a progressive decline thereafter.111 In men, age-related bone loss occurs at a rate of approximately 5% per decade,112,113 whereas women experience a more rapid loss (approximately 10% per decade) from the onset of menopause.114 From the age of 75 years, bone loss slows to approximately 3% per decade.112–114 Possibly in response to these changes in bone density, older people’s bones (both cortical and cancellous) also demonstrate a higher proportion of microfractures.115

#### JOINTS

Although the alignment and morphology of lower limb joints differ considerably depending on their function, the basic structure is essentially the same. Each of the bones comprising the joint is covered with a thin layer of articular cartilage. The space between the bones, the joint cavity, is lined by a synovial membrane, which secretes synovial fluid, enabling smooth movement of one bone over the other. Encasing the synovial membrane is the joint capsule, which consists of strong but flexible collagen...
fibres, and binding the entire joint together are ligaments, which are also primarily composed of collagen fibres.

Much of the research relating to age-related changes in joints has focused on cartilage, because of its role in the development of osteoarthritis. Cartilage is a dense connective tissue comprising cells (called chondrocytes) dispersed in a matrix of various types of collagen, proteoglycans and other matrix proteins, and water. The matrix provides cartilage with the ability to withstand compressive, tensile and shear forces generated during movement. Degradation of cartilage is a complex process influenced not only by age but also nutrition, individual mechanical joint characteristics and level of physical activity. Furthermore, it is difficult to delineate age-related changes from those associated with osteoarthritis.

Nevertheless, several changes in articular cartilage do appear to be related to the ageing process. At the molecular level, there is a gradual reduction in the amount of chondroitin sulphate and oligosaccharides, and a corresponding increase in keratan sulphate. Collagen fibril width and cross-linking increase with age, and the water content decreases. Somewhat surprisingly, the cell content and thickness of articular cartilage does not appear to change appreciably with age, and joint surfaces in older people may be more congruent than those of younger people. The latter observation has been explained by the notion that some level of incongruence is a normal feature of a healthy joint, in order to provide access of synovial fluid to the cartilage and allow for controlled loading.

With ageing, this protective mechanism becomes less effective, and the joint may be in a state of constant loading.

In addition to these changes in cartilage structure and function, ageing also results in a stiffening of the synovial membrane and a reduction in its ability to produce synovial fluid. As with ageing cartilage, there is a reduction in the amount of chondroitin sulphate in the synovial fluid, which may influence its viscosity. Collagen cross-linking also results in a shortening and stiffening of the joint capsule and supporting ligaments.

## TENDON AND LIGAMENT

The primary function of tendons is to transmit muscle force to the skeletal system, whereas the function of ligaments is to bind bones together and restrict excessive movement. Despite this difference in function, the structure of tendons and ligaments is similar – both structures consist primarily of collagen fibrils embedded in a matrix of proteoglycans. Evaluating the effect of ageing on the structure of human tendons and ligaments, however, is inherently difficult because of the need to biopsy tissue. As a consequence, much of our knowledge regarding the biochemical and histological changes in these structures stems from animal models (most commonly rat tails or the Achilles tendons of rabbits), cadavers, or tendons and ligaments harvested from surgical cases. These investigations have revealed that advancing age results in significant increases in collagen fibril
concentration and diameter, and increased spacing and cross-linking of collagen molecules, factors thought to be indicative of non-enzymatic glycosylation. Non-collagenous components of tendon have also been shown to undergo changes with age, with decreases in the water content of glycosaminoglycans and increases in lipid content.

A small number of studies have directly evaluated structural changes in the human Achilles tendon. Snow et al. analysed gross anatomy and histological sections of Achilles tendons obtained from neonatal, young and old cadavers, and reported a progressive reduction in the number of fibres connecting the tendon to the plantar fascia with advancing age. In the older group, a band of periosteum clearly separated the insertion of the Achilles tendon and the plantar fascia. Using light and electron microscopy, Strocchi et al. evaluated 15 cadaver Achilles tendons up to 87 years of age and reported that ageing was associated with a decrease in the diameter but an increase in the concentration of collagen fibrils. Similar results were reported by Sargon et al. in 28 Achilles tendon specimens obtained from patients undergoing heel surgery. Finally, using magnetic resonance imaging, Magnusson et al. demonstrated that older women have a larger Achilles tendon cross-sectional area than younger women, reflecting the age-related hypertrophy evident in animal studies.

**FUNCTIONAL IMPLICATIONS**

The functional implications of an ageing skeletal system are considerable. Changes in bone density are strongly linked to the development of osteoporosis, the prevalence of which increases exponentially with age. Although the most serious consequences of osteoporosis are vertebral, femoral and radius fractures, insufficiency fractures of the foot may also occur, most commonly in the metatarsals but also in the calcaneus and talus. Such fractures are frequently misdiagnosed and often lead to impaired mobility. Ageing is also a significant risk factor for osteoarthritis, which affects the first metatarsophalangeal joint of the foot in 44% of people over the age of 80 years.

Changes in joint tissues may also be responsible for the reduced range of motion of lower extremity joints in older people. Several studies have shown that ankle dorsiflexion–plantarflexion range of motion reduces with age and Nigg et al. have also noted a significant reduction in inversion–eversion and abduction–adduction motion of the ankle joint complex. Of particular note, women generally exhibited greater range of motion than men but also demonstrated greater reductions in ankle dorsiflexion and eversion with age. More recently, Scott et al. showed that older people had significantly less range of motion at the ankle joint (36° versus 45°, using a weightbearing lunge test) and less passive range of motion the first metatarsophalangeal joint (56° versus 82°, measured non-weightbearing) compared to younger controls. Assessment of foot posture also indicated that older people had significantly flatter feet, as indicated by a higher foot posture index and arch index, and a reduction in the height of the navicular tuberosity.

Reduction in joint range of motion in the foot is strongly associated with impaired balance and functional ability and increases the risk of falls, while the progressive flattening of the arch may predispose to the development of posterior tibial tendon dysfunction, a disorder in which the tendon becomes progressively weakened and elongated, resulting in a painful flatfoot deformity. There is also emerging evidence that restricted range of motion in the ankle joint may impair the function of the calf muscle pump, thereby contributing to the development of venous disorders of the lower limb.

Finally, despite having a reduced overall risk of tendon rupture because of their reduced exposure to ballistic activities, older people have an increased risk of tendon rupture when performing non-sporting activities, possibly due to age-related increases in tendon stiffness.

**MUSCULAR SYSTEM**

**AGE-RELATED CHANGES IN MUSCLE TISSUE**

Muscle fibres consist of elongated actin and myosin filaments encased in a tubular membrane. Broadly speaking, two types of fibre have been identified: type I fibres, which contract slowly and can stay contracted for long periods of time before fatiguing, and type II fibres, which contract more quickly but also fatigue more easily. One of the most characteristic features of advancing age is the inevitable reduction in the total mass of muscle fibres, often referred to as sarcopenia (adapted from the Greek, meaning ‘poverty of the flesh’). Muscle mass accounts for 40% of
the total body weight of young people but this reduces to approximately 25% of total body weight in older people. This reduction in muscle mass is strongly correlated with the reduction in total muscle cross-sectional area, which has been shown to decrease by approximately 40% between the ages of 20 and 60 years and involves reductions in both the size and number of muscle fibres. Although preliminary research suggested that age-related loss of muscle fibres specifically affected type II fibres, more recent evidence indicates that although ageing results in a reduction in the size of type II fibres, the relative proportion of type I and type II fibres is largely unaffected by age. However, ageing also results in motor unit remodelling, a process in which type II fibres are denervated and then reinnervated by collateral branches of type I fibres, resulting in the formation of large, slow-twitch motor units. A summary of these changes is provided in Table 2.5.

<table>
<thead>
<tr>
<th>Age-related changes</th>
<th>Implications</th>
</tr>
</thead>
<tbody>
<tr>
<td>↓ total muscle mass</td>
<td>↓ ankle dorsiflexion and plantarflexion strength</td>
</tr>
<tr>
<td>↓ muscle cross-sectional area</td>
<td>↓ toe plantarflexion strength</td>
</tr>
<tr>
<td>↓ size of Type II fibres</td>
<td>↓ balance</td>
</tr>
<tr>
<td>Development of large, slow-twitch motor units</td>
<td>↓ walking speed</td>
</tr>
<tr>
<td></td>
<td>↑ risk of falls</td>
</tr>
</tbody>
</table>

As stated above, most studies addressing age-related differences in strength have examined quadriceps muscles; however, some have focused on ankle muscles. One of the earliest studies to assess age-associated changes in ankle muscle function was that of McDonagh et al, who compared ankle plantarflexor strength in young and older men and reported that the maximum voluntary contraction in older subjects was 20% weaker than in young subjects. A comparison of these results with those of arm flexor strength suggested that ankle plantarflexors were more significantly affected by advancing age. More recent investigations have largely confirmed these results. Vandervoort & McComas reported that the strength of ankle plantarflexor and dorsiflexor muscles declined with advancing age but the differences were most marked from late middle age onwards. Van-Schaik et al reported that ankle dorsiflexion strength was significantly decreased in subjects aged 60–80 years compared to subjects aged 20–40 years. Similarly, Winegard et al compared ankle plantarflexor strength in subjects aged 20–91 years and found that strength significantly decreased with advancing age. Although considerable differences in study populations and methods used make direct comparisons of these investigations difficult, it can be concluded that older people exhibit between 30% and 60% of the ankle strength of younger people.

FOOT MUSCLES

Although it has long been suspected that ageing is associated with atrophy of intrinsic foot muscles, evidence to support such an assertion is scarce. Recent studies using magnetic resonance imaging in people with and without diabetes indicates significant reductions in the volume of ankle plantarflexors and intrinsic foot muscles associated with the disease. Given that many of the neuromuscular changes that occur in diabetes are similar to those of advancing age, it is likely that comparisons between healthy young and older people would reveal similar, but not as marked, differences in foot muscle volume.

Only two studies have investigated age-related changes in the strength of foot muscles. Endo et al measured the force applied by the toes in 20 young and 20 older participants when instructed to place all their bodyweight on their forefoot while leaning forwards as far as possible. The results revealed that older participants generated 29% less force than younger
participants. However, the contribution of ankle plantarflexor strength using this testing procedure cannot be discounted and it is likely that the amount of force applied by the toes was also influenced by balance ability. Furthermore, this approach is incapable of delineating between the strength of the hallux and the lesser toes. To address these issues, Menz et al.\textsuperscript{172} used a pressure platform to measure toe plantarflexor strength in 40 young and 40 older participants while seated. The results indicated that older participants exhibited 32\% less plantarflexion strength of the hallux and 27\% less plantarflexion strength of the lesser toes compared to younger participants, and women exhibited 42\% less hallux plantarflexor strength than men. However, sex did not influence lesser toe plantarflexor strength.

**FUNCTIONAL IMPLICATIONS**

The key functional implication of an ageing muscular system is its effect on functional mobility in older people. Lower limb strength is strongly associated with balance,\textsuperscript{98} walking speed\textsuperscript{105,173} and the ability to rise from a chair\textsuperscript{174} and, subsequently, loss of strength is a major contributor to falls\textsuperscript{175} and overall functional decline.\textsuperscript{176} However, there is solid evidence that age-related loss of strength and its functional consequences can be partly prevented, and possibly partly reversed, by resistance training.\textsuperscript{153} Secondly, although several authors have suggested that atrophy and/or imbalance of foot muscles may be related to the development of hallux valgus\textsuperscript{177,178} and lesser toe deformities,\textsuperscript{169} the role of muscle weakness in the development of foot deformity remains unclear.

**SUMMARY**

Normal ageing has a significant effect on the structure and function of the foot and these changes have considerable implications for the development of foot problems. A sound knowledge of these changes is essential for clinicians involved in the assessment and management of foot disorders in older people.

**References**

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Assessment

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THE INITIAL ASSESSMENT INTERVIEW

The initial assessment interview is one the most important components of lower limb assessment in older people. A considerable amount of relevant information can be gleaned from a thorough and targeted evaluation of medical and social history – information that in many cases will influence the management strategy and assist in determining the likelihood of a successful outcome. Because of the high prevalence of visual, auditory and cognitive impairment in older people, it is essential that the initial assessment interview is conducted in a quiet, well lit and unhurried clinical environment. History taking in older people may also require the aggregation of information from multiple sources, including family members, friends and carers. This can be challenging, particularly when the information gathered is inconsistent. In some cases it may be necessary to obtain relevant information from each of these sources in isolation in order to develop a more accurate picture of the presenting complaint. This clearly requires striking a balance between patient confidentiality and family involvement.1 An outline of areas to be covered in the initial assessment is provided in Table 3.1.

MEDICAL AND SOCIAL HISTORY

Previous and current medical conditions should be documented. In addition to current and previous medical conditions (including previous surgery), documenting a family history may provide useful insights into undiagnosed conditions with a strong hereditary
predisposition (such as diabetes mellitus and psoriasis). To assist in recall, drawing a pedigree chart may be useful (Fig. 3.1), although in older patients it will be difficult to document family history accurately beyond one previous generation.

Documenting a thorough social history is essential to the management of foot problems in older people, as chronic foot conditions will often require ongoing self-management by the older person in their home environment. Inspection of foot lesions, use of appropriate footwear and regular changing of wound dressings are all aspects of care that may be compromised if the level of social support is inadequate. Thorough questioning of the older person’s household situation may also highlight limitations in the awareness of supportive care services (such as community nursing) that the older person may be eligible to access. Current

<table>
<thead>
<tr>
<th>Component</th>
<th>Areas to be covered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medical history</td>
<td>Current overall health status and diagnosed medical conditions</td>
</tr>
<tr>
<td></td>
<td>Current medications</td>
</tr>
<tr>
<td></td>
<td>Previous medical history (including previous surgery)</td>
</tr>
<tr>
<td></td>
<td>Family history</td>
</tr>
<tr>
<td></td>
<td>Cognitive status</td>
</tr>
<tr>
<td>Social history</td>
<td>Age</td>
</tr>
<tr>
<td></td>
<td>Gender</td>
</tr>
<tr>
<td></td>
<td>Ethnicity</td>
</tr>
<tr>
<td></td>
<td>Social habits</td>
</tr>
<tr>
<td></td>
<td>Sporting/leisure activity</td>
</tr>
<tr>
<td></td>
<td>Spouse/family/carer support</td>
</tr>
<tr>
<td>Presenting complaint</td>
<td>Location, duration, severity, previous treatments</td>
</tr>
<tr>
<td>Systems examination</td>
<td>Dermatological</td>
</tr>
<tr>
<td></td>
<td>Vascular</td>
</tr>
<tr>
<td></td>
<td>Neurological</td>
</tr>
<tr>
<td></td>
<td>Musculoskeletal</td>
</tr>
<tr>
<td>Diagnostic imaging</td>
<td>Radiography, bone scanning, ultrasonography, computed tomography, magnetic resonance imaging</td>
</tr>
<tr>
<td>Functional assessment</td>
<td>Activities of daily living</td>
</tr>
<tr>
<td></td>
<td>Mobility</td>
</tr>
<tr>
<td></td>
<td>Gait disorders</td>
</tr>
<tr>
<td></td>
<td>Falls risk assessment</td>
</tr>
<tr>
<td></td>
<td>Ability to self-care</td>
</tr>
<tr>
<td>Footwear assessment</td>
<td>Shoe fit and suitability</td>
</tr>
<tr>
<td></td>
<td>Wear patterns</td>
</tr>
</tbody>
</table>

Figure 3.1 Example of a pedigree chart for investigating hereditary predisposition to disease. Squares represent males, circles represent females. Diagonal lines represent deceased family members, shaded circle represents the patient.
and previous occupation and level of physical activity may both be contributing factors to the development of foot problems and should be thoroughly evaluated.

**MEDICATION USE**

Because of the age-related increased prevalence of chronic conditions, the use of prescription and over-the-counter medications increases dramatically with advancing age, with over 80% of people aged over 65 years taking at least one medication and at least 20% taking five or more.² Although not all clinicians involved in the management of older people have the scope of practice to prescribe or withdraw medications, all health-care professionals should thoroughly document medication use at the initial assessment, undertake regular reviews of medication use and be wary of potential adverse reactions. It is often necessary to request that older people bring their medications to their clinical appointments to ensure accuracy in documentation, and to ask specific questions regarding over-the-counter medications such as vitamin supplements, herbal medications, eye drops, creams and ointments. The use of herbal medications and supplements is highly prevalent among older people; however, clinicians often do not document their use and older patients may not report them during the medical history interview. A study of 1539 older people recently found that, while 34% used some form of herbal medication, 70% had not informed their physician.³ This is problematic, as all medications, irrespective of their prescription status, have the potential to interact and contribute to adverse events. Common herbal medications that have been shown to have clinically important interactions with prescription medications include St John’s wort, gingko biloba, echinacea, saw palmetto, garlic and ginseng.⁴,⁵

**ASSESSMENT OF COGNITIVE STATUS**

Evaluating an older person’s cognitive status is an important aspect of lower limb assessment in older people for two major reasons. Firstly, obtaining informed consent to commence a clinical intervention requires that the older person is fully cognisant of the implications of the decision they are making. This is particularly important in relation to more invasive procedures such as foot surgery, where the advantages and disadvantages need to be carefully considered. Secondly, the success of many clinical management strategies is dependent on the ability of the older person to undertake activities after they leave the clinical environment. Failure to assess whether the older person is capable of undertaking these tasks may significantly reduce the likelihood of a good clinical outcome.

Although the astute clinician may be able to detect moderate to severe levels of cognitive impairment from general observations and history taking, a structured approach using validated assessment tools will yield more valid findings. The most commonly used clinical screening tool for cognitive evaluation is the Mini-Mental State Examination (MMSE), a clinician-administered questionnaire consisting of 30 questions addressing several components of cognitive function.⁶ However, the MMSE is generally not feasible to implement into routine clinical practice because of its length. In recognition of this, several shorter screening tools have been developed that are highly correlated with the MMSE. The simplest and most widely used of these tests is the Clock Drawing Test (CDT).⁷ Although several versions of this test exist, the most basic approach requires requesting the patient to draw a clock face with all the numbers and hands placed correctly, and to then state the time they have drawn. The following scoring system is then applied: (a) the number 12 appears on top (3 points); (b) there are 12 numbers present (1 point); (c) there are two clearly distinguishable hands (1 point); and (d) the time is correctly stated (1 point). Scores of less than 4 are indicative of moderate to severe cognitive impairment⁸ and warrant further diagnostic evaluation by a geriatrician. Examples of the CDT are shown in Figure 3.2.

![](image.png)

**Figure 3.2** Examples of the clock-drawing test of cognitive impairment. **A.** Normal (score 6). **B.** Moderate cognitive impairment (score 4). **C.** Severe cognitive impairment (score 0).
THE PRESENTING COMPLAINT

Location and history of the presenting complaint

Having established a thorough medical and social history and evaluated the cognitive status of the older person, the next step in the assessment process is to specifically address the presenting complaint. The key questions that should be asked are listed in Table 3.2, along with some example answers. The location of the presenting complaint should first be accurately identified. The use of visual aids, such as anatomical diagrams or models, can be very useful in determining the location of the problem, particularly if the older person has difficulty describing the location or is physically incapable of pointing to it (Fig. 3.3). Direct questioning regarding symptoms in other body regions may also provide useful diagnostic clues that may not have been otherwise volunteered.

Pain assessment

Because pain is the most common reason for seeking medical care, it is important to assess the characteris-

Table 3.2 Key questions to ask about the presenting complaint – the example answers are those that may suggest an ingrown toenail

<table>
<thead>
<tr>
<th>Questions</th>
<th>Example answers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Where is the problem?</td>
<td>My big toenail</td>
</tr>
<tr>
<td>2. How long have you had the problem?</td>
<td>Two weeks</td>
</tr>
<tr>
<td>3. How did it start?</td>
<td>I stubbed my toe in the garden</td>
</tr>
<tr>
<td>4. When does the problem trouble you?</td>
<td>When I’m walking</td>
</tr>
<tr>
<td>5. What makes the problem better?</td>
<td>Taking my shoes off and soaking my feet</td>
</tr>
<tr>
<td>6. What makes the problem worse?</td>
<td>Wearing my slippers</td>
</tr>
<tr>
<td>7. What treatments have you already tried?</td>
<td>Wrapping my toe with cotton wool</td>
</tr>
</tbody>
</table>

Right foot

Left foot

Figure 3.3 Anatomical map to assist in the documentation of pain location.
tics and severity of pain in older people with foot problems. Pain descriptors used by the patient, such as the nature of the pain sensation (e.g. burning, aching, stinging, throbbing), the distribution of pain (e.g. localised, radiating, superficial, deep) and patterns of pain (e.g. persistent, occasional, periodic) can greatly assist in reaching a diagnosis of the presenting complaint. Pain intensity can be evaluated using several generic pain rating scales (such as the McGill Pain Questionnaire); however, these scales are generally too time-consuming for routine administration in the clinical setting and may not always be relevant for foot disorders. Visual analogue scales, numerical rating scales and verbal descriptor scales are useful indicators of pain intensity, are easily understood and are simple and quick to administer; however, they do not provide any insights into the functional and psychosocial impairments associated with pain. Furthermore, there is evidence that the visual analogue scale may not be appropriate for all older people, as many have difficulty transforming the subjective nature of pain into a metric scale.

Several foot-specific pain and disability questionnaires have recently been developed, including the Foot Function Index, the Foot Health Status Questionnaire, a range of scales developed by the American Orthopedic Foot and Ankle Society, the Manchester Foot Pain and Disability Index, which was originally developed by Garrow et al. The MFPDI consists of 19 statements prefaced by the phrase ‘Because of pain in my feet’, formalised under three constructs: functional limitation (10 items), pain intensity (five items), and personal appearance (two items), with three possible answers: ‘none of the time’ (score = 0), ‘some days’ (score = 2), and ‘most days/every day’ (score = 3). The remaining two items are concerned with difficulties in performing work or leisure activities, which are omitted if the respondent is of retirement age.

Menz et al recently administered the MFPDI to 301 people aged over 75 years of age and found that the factor weightings in older people slightly differed from the initial validation study. In the Menz et al study, the MFPDI was found to exhibit high internal consistency and represent four

<table>
<thead>
<tr>
<th>Question</th>
<th>Original validation domains</th>
<th>Domains in older people</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I avoid walking outside at all</td>
<td>Functional limitation</td>
<td>Activity restriction</td>
</tr>
<tr>
<td>2. I avoid walking distances</td>
<td>Functional limitation</td>
<td>Functional limitation</td>
</tr>
<tr>
<td>3. I don’t walk in a normal way</td>
<td>Functional limitation</td>
<td>Functional limitation</td>
</tr>
<tr>
<td>4. I walk slowly</td>
<td>Functional limitation</td>
<td>Functional limitation</td>
</tr>
<tr>
<td>5. I have to stop and rest my feet</td>
<td>Functional limitation</td>
<td>Functional limitation</td>
</tr>
<tr>
<td>6. I avoid hard or rough surfaces where possible</td>
<td>Functional limitation</td>
<td>Functional limitation</td>
</tr>
<tr>
<td>7. I avoid standing for a long time</td>
<td>Functional limitation</td>
<td>Functional limitation</td>
</tr>
<tr>
<td>8. I catch the bus or use the car more often</td>
<td>Functional limitation</td>
<td>Activity restriction</td>
</tr>
<tr>
<td>9. I need help with housework/shopping</td>
<td>Functional limitation</td>
<td>Pain intensity</td>
</tr>
<tr>
<td>10. I still do everything but with more pain or discomfort</td>
<td>Pain intensity</td>
<td>Pain intensity</td>
</tr>
<tr>
<td>11. I get irritable when my feet hurt</td>
<td>Functional limitation</td>
<td>Pain intensity</td>
</tr>
<tr>
<td>12. I feel self-conscious about my feet</td>
<td>Concern about appearance</td>
<td>Concern about appearance</td>
</tr>
<tr>
<td>13. I get self-conscious about the shoes I have to wear</td>
<td>Concern about appearance</td>
<td>Concern about appearance</td>
</tr>
<tr>
<td>14. I have constant pain in my feet</td>
<td>Pain intensity</td>
<td>Pain intensity</td>
</tr>
<tr>
<td>15. My feet are worse in the morning</td>
<td>Pain intensity</td>
<td>Pain intensity</td>
</tr>
<tr>
<td>16. My feet are more painful in the evening</td>
<td>Pain intensity</td>
<td>Pain intensity</td>
</tr>
<tr>
<td>17. I get shooting pains in my feet</td>
<td>Pain intensity</td>
<td>Pain intensity</td>
</tr>
</tbody>
</table>
pain domains: functional limitation, pain intensity, concern about appearance and activity restriction (Table 3.3). These results indicate that MFPDI is an appropriate tool for assessing foot pain in older people. In addition, the MFPDI has been shown to be sensitive to improvement following a self-management intervention, suggesting that it may also have some value as a measure of treatment efficacy.

Assessing pain in older people who are incapable of verbal communication is a considerable challenge and requires observation of physical responses (such as guarding, fidgeting or restricted movement of the painful body part) and facial expressions (such as frowning, grimacing or excessive blinking). Clinicians should never assume that those who are incapable of reporting pain do not experience it, and all attempts should be made to ensure that physical examination procedures are as pain-free as possible.

**SYSTEMS EXAMINATION**

Systems examination of the lower limb in older people should be essentially the same as that for younger people; however, there are some particular issues that require additional consideration. The most fundamental issue in relation to systems examination in the older patient is the tendency for some clinicians to undertake less thorough assessments, because of the incorrect assumption that many aspects of ageing cannot be effectively managed. This is by no means limited to foot-care specialists – indeed, ageist assumptions have been demonstrated in most fields of medicine and often result in less detailed diagnostic approaches and the provision of less aggressive treatment approaches. Systems examination of the lower limb in older people is likely to have a high diagnostic yield, and older people may be more likely to benefit from thorough assessments than younger, relatively healthy patients.

**DERMATOLOGICAL ASSESSMENT**

Thorough visual observation is the most fundamental component of dermatological assessment of the lower limb in older people, as many skin lesions have characteristic patterns of presentation. Skin lesions should be carefully examined in relation to their arrangement, shape, size, surface contour and colour (Fig. 3.4), and the lesion type should be documented using widely accepted dermatological nomenclature (Table 3.4). Careful palpation of the skin may also yield useful clinical information regarding the texture, depth, consistency and contents of the lesion.

Assessment of skin dryness in the clinical setting can be standardised using the xerosis scale developed by Rogers et al. This scale consists of six images of feet with varying degrees of skin dryness, ranging from a mild, dusty appearance with some small skin flakes to large scaly plates and deep fissuring (Fig. 3.5). Although the scale has not yet been validated against gold standard measurements of skin hydration (such as electrical capacitance), it has been shown to be a sensitive measurement of skin hydration in response to emollient application.

In addition to clinical observations, investigations such as mycology, bacterial and viral culture, and histological assessment may be necessary. Mycology is particularly important in relation to confirmation of suspected onychomycosis in older people for two main reasons. Firstly, dystrophic nails may test positive for a wide range of organisms, necessitating the use of broad-spectrum antibiotics or antifungals. Secondly, in approximately 20% of cases of suspected onychomycosis, no fungal organisms can be identified, suggesting that, as a result of misdiagnosis, some older people may undergo unnecessary antifungal
Bacterial and viral culture should be considered in the case of longstanding paronychia or suspected secondary bacterial infection of pustular lesions or open wounds. It is essential that foot-care specialists establish good communication with their local pathology providers to ascertain their sampling and transport requirements.

In general, all foot lesions in older people should also be investigated for evidence of underlying tissue breakdown and ulceration, and chronic lesions should be carefully documented for potential malignant changes. The ABCD mnemonic (A – asymmetry; B – border irregularity; C – change in colour and D – increase in diameter) is a useful general rule for routine assessment of suspect lesions. A particularly high index of suspicion should also be applied to non-healing subungual lesions, as this is a relatively common site for the development of malignant melanomas. This is discussed in more detail in Chapter 5.

If skin breakdown is noted during a dermatological assessment, more detailed wound assessments need to be undertaken. Wound assessment, although not an exact science, is essential for two main reasons. Firstly, assessing the characteristics of a wound (such as the underlying aetiology, location, size and presence or absence of infection) may inform the selection of treatment; and secondly, assessing the severity of a wound can provide useful insights into the risk of further complications such as infection and amputation. A summary of key features to document when assessing wounds is provided in Table 3.5.

Wound severity can be assessed using the Wagner classification, which includes five grades: grade 1 (loss of dermal tissue only), grade 2 (loss of tissue that exposes tendon or bone), grade 3 (loss of tissue that exposes tendon or bone with osteomyelitis or abscess), grade 4 (gangrene of digits or forefoot) and grade 5 (extensive gangrene of the foot). The more recent
University of Texas classification includes three grades: grade 0 (pre- or postulcerative site that has healed), grade 1 (superficial wound not involving tendon, capsule or bone), grade 2 (wound penetrating to tendon or capsule) and grade 3 (wound penetrating bone or joint). Within wound grade there are four stages: clean wounds (stage A), non-ischaemic infected wounds (stage B), ischaemic noninfected wounds (stage C) and ischaemic infected wounds (stage D). While both scales are clinically useful, the University of Texas scale has been found to be more predictive of healing time. Management of wounds is discussed in Chapter 7.

**VASCULAR ASSESSMENT**

As outlined in Chapter 2, ageing is associated with significant changes in the structure and function of peripheral blood vessels, resulting in reduced function of both the peripheral arterial and venous systems. These changes commonly manifest in the foot and ankle, increasing the risk of arterial insufficiency, venous stasis and ulceration. A thorough vascular assessment is therefore an essential component of lower limb evaluation.

**Assessment of the peripheral arterial system**

Age is a major independent risk factor for the development of peripheral arterial disease (PAD). PAD affects approximately 15% of people aged 70 years and over but often goes unrecognised in a large number of patients until the onset of symptoms. Given that many older people with asymptomatic PAD have evidence of subclinical cardiovascular disease, lower limb arterial supply has been described as one of the ‘vital signs’ of an older person’s health status, and foot-care specialists are well placed to detect early signs of vascular disease in asymptomatic older people.

The severity of PAD can be classified according to the presenting symptoms, using the widely used Fontaine classification (Table 3.6). The classical early presentation of ischaemically induced pain is intermittent claudication, a tight, cramping pain in the calf region (or, less commonly, in the thigh, buttocks or foot) that occurs when walking and is relieved by rest. Intermittent claudication is thought to result from the build-up of metabolites in response to reduced oxygenation of the surrounding muscle. When the older person rests, the metabolites are gradually cleared from the surrounding muscle, allowing for improved oxygenation and relief of pain. Table 3.6 The Fontaine classification of peripheral arterial disease

<table>
<thead>
<tr>
<th>Stage</th>
<th>Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Asymptomatic</td>
</tr>
<tr>
<td>2</td>
<td>Intermittent claudication</td>
</tr>
<tr>
<td>3</td>
<td>Ischaemic rest pain</td>
</tr>
<tr>
<td>4</td>
<td>Severe rest pain with ulceration or gangrene, or both</td>
</tr>
</tbody>
</table>
cleared and the oxygen requirement of the muscles is reduced, leading to an alleviation of symptoms. An accurate diagnosis of intermittent claudication can be obtained using a series of six questions, referred to as the Edinburgh Claudication Questionnaire (Table 3.7). This questionnaire has been found to have a sensitivity of 99% and a specificity of 91% in 300 symptomatic patients aged 55 years and over.30

In more advanced PAD, a similar cramping pain may develop in bed (referred to as nocturnal or night cramps) as the heat of the bedclothes increases the oxygen demand of the legs. Hanging the affected limb over the side of the bed relieves the pain as a result of a reduction in limb temperature and gravity-induced increase in blood flow. Finally, the most severe form of ischaemic pain occurs in the absence of any physical activity (referred to as rest pain) and indicates that the arterial supply of the limb cannot even meet quiescent metabolic requirements. At this stage, the limb is so severely ischaemic that ulceration and/or gangrene may develop – a state commonly referred to as critical limb ischaemia, which infers that, if limb perfusion cannot be improved, there is a significant risk of limb failure and subsequent amputation.31

Table 3.7 The Edinburgh Claudication Questionnaire

<table>
<thead>
<tr>
<th>Question</th>
<th>Response</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do you get pain or discomfort in your leg(s) when you walk?</td>
<td>Yes (if patient answers No, stop here)</td>
<td>99.3</td>
<td>13.1</td>
</tr>
<tr>
<td>Does this pain ever begin when you are standing still or sitting?</td>
<td>No</td>
<td>99.3</td>
<td>80.3</td>
</tr>
<tr>
<td>Do you get pain if you walk uphill or in a hurry?</td>
<td>Yes</td>
<td>98.8</td>
<td>13.1</td>
</tr>
<tr>
<td>Do you get pain if you walk at an ordinary pace on level ground?</td>
<td>Yes or No, depending on severity of claudication</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>What happens if you stand still?</td>
<td>Pain gone in 10 min or less</td>
<td>90.6</td>
<td>63.9</td>
</tr>
<tr>
<td>Where do you get this pain?</td>
<td>Calf,* thigh† or buttock†</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

A positive classification of claudication requires the indicated response for all questions.
*definite claudication = pain in calf. †Atypical claudication = pain in thigh or buttock in the absence of calf pain.

In addition to the documentation of ischaemic symptoms, clinical examination of suspected PAD encompasses simple visual observations (such as loss of hair growth, atrophic or shiny skin and dystrophic toenails), palpation (assessment of limb temperature and palpation of pedal pulses), observation of changes in blood flow following occlusion (the capillary refill time test) or limb elevation (Buerger’s test), and assessment of abnormal sounds detected with a stethoscope (bruits). Two recent reviews of physical examination procedures for PAD32,33 indicated that many of these observations are highly specific (i.e. their absence precludes the diagnosis of PAD) but have low sensitivity (i.e. their presence does not necessarily indicate that PAD is present). The most useful clinical observations in detecting PAD were found to be abnormal pedal pulses, femoral artery bruit, unilateral cool limb and abnormal limb colour (Table 3.8).

Although clinical observations remain an important component of peripheral arterial assessment, far greater diagnostic accuracy can be achieved by calculating the ankle–brachial index (ABI) using a sphygmomanometer and stethoscope or Doppler ultrasound.34 The basic principle of the ABI is that systolic blood pressure in the lower limb should be equal to or slightly greater than that in the upper limb. By dividing systolic blood pressure in the lower limb by the pressure in the upper limb, an index can be calculated which provides a sensitive marker of peripheral blood supply.35 To perform the test, the patient is placed in a supine position with one arm flexed at the elbow and a blood pressure cuff is placed around the upper arm and inflated until the brachial pulse can no longer be heard with the stethoscope or Doppler. The cuff is then released slowly and the point at which the pulse returns is documented from
the manometer. The test is then repeated with the cuff placed above the ankle joint and the stethoscope or Doppler placed over the posterior tibial or dorsalis pedis artery.

There are several variations of the ABI technique in relation to the lower limb artery used (dorsalis pedis, posterior tibial or both), how left and right readings are calculated (the highest, the lowest or the average) and the number of tests performed.36 Similarly, several scoring systems have been devised, with normal values ranging from 0.9 to 1.5, and the PAD cut-off value being reported as either less than 0.9 or less than 1.0.36 In response to these variations, the Standards Division of the Society of Interventional Radiology recently developed a consensus statement for the use of the ABI.37 This statement recommends that the higher pressure of the dorsalis pedis or posterior tibial artery for each foot be divided by the highest brachial artery pressure. The Division also recommended that the cut-off value for an abnormal reading should be less than 1.0, with rest pain typically occurring in patients with an ABI less than 0.5 and critical ischaemia associated with an ABI of less than 0.2.37

ABI values need to be interpreted with caution in patients with Mönckeberg’s sclerosis or diabetes, as the calcification of the arterial wall associated with these conditions may prevent adequate compression of the artery, thereby leading to falsely elevated index scores. Clinicians should suspect artery wall calcification if the vessel cannot be compressed with pressures above 200 mmHg or if the ABI calculated is well above 1.0 in the presence of other visual signs of ischaemia. If this occurs, there are two alternative approaches that can be used. Firstly, the peroneal artery is rarely affected by calcification, so the ABI can be calculated using the peroneal artery pressure value rather than the dorsalis pedis or posterior tibial arteries. Secondly, the pole test described by Smith et al38 can be used, which involves placing the patient in a supine position, elevating the leg until the pulse can no longer be detected and measuring the vertical distance between the heart and the foot. A distance less than 40 cm is indicative of severe occlusion.

More advanced techniques for the assessment of lower limb ischaemia, such as exercise testing, Duplex scanning, computed tomography and magnetic resonance angiography are the domain of the specialist vascular surgeon and are generally only indicated for presurgical planning for bypass or limb salvage procedures.34 Referral for these investigations is indicated where there is evidence of severe PAD, particularly if rest pain, ulceration or gangrene are present.

### Assessment of the peripheral venous system

Venous disorders are also common in older people39 and therefore clinical evaluation of venous insufficiency, including observations of telangiectasis, varicosities, oedema and venous ulcers, should also be a routine component of geriatric lower limb assessment. Clinical observation is generally sufficient to arrive at a diagnosis of venous insufficiency; however, the Perthes manoeuvre can provide further insight into the competency of leg veins. This test involves the application of a blood pressure cuff at mid thigh level while the leg is dependent. The patient is then instructed to walk and rise up on to their toes to stimulate the calf muscle pump. In a normal limb, the superficial veins will empty into the deep vein system because of the action of the calf muscles; however, in the presence of valvular incompetence, the superficial veins will remain distended and the limb may become erythematous.

It has also recently been demonstrated that the assessment of foot veins provides a useful insight into the hydration status of an older person.40 Given that

<table>
<thead>
<tr>
<th>Test</th>
<th>Test result indicative of peripheral arterial disease</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abnormal pedal pulse</td>
<td>Dorsalis pedis and posterior tibial artery pulses both absent, or one present and one weak</td>
<td>63</td>
<td>99</td>
</tr>
<tr>
<td>Femoral artery bruit</td>
<td>Bruit present</td>
<td>29</td>
<td>95</td>
</tr>
<tr>
<td>Cool skin</td>
<td>Unilateral cool skin</td>
<td>10</td>
<td>98</td>
</tr>
<tr>
<td>Abnormal limb colour</td>
<td>Pale, red or blue limb</td>
<td>35</td>
<td>87</td>
</tr>
</tbody>
</table>

---

Table 3.8 Clinical observations indicative of peripheral arterial disease
dehydration is very common in older people (particularly those in institutional care), this simple assessment may help in the early detection of impaired fluid balance. To perform the assessment, the dorsal venous arch vein is occluded by finger pressure and the vein is emptied by stroking proximally. The finger is then released, and the rate and degree of venous return is observed, with a delay of more than 3 seconds being indicative of potential dehydration.

The most serious and potentially life-threatening lower limb venous disorder, deep vein thrombosis (DVT), should always be suspected in older people presenting with a hot, painful, swollen leg. However, because anticoagulant therapy has potentially serious side effects, it is important that DVT is also accurately ruled out when it is not present. To assist in this process, the clinical prediction rule of Wells et al41 is particularly useful (Table 3.9). This consists of 12 medical history items and clinical observations that can easily be undertaken as part of a routine consultation. The classification of a patient as having a ‘high clinical probability’ of DVT on this scale has been shown to have 91% sensitivity and 100% specificity for the eventual imaging diagnosis of DVT.

Definitive diagnosis of DVT requires referral to a vascular laboratory for imaging techniques such as contrast venography, ultrasonography, computed tomography or magnetic resonance imaging.42 Contrast venography, which involves X-raying the limb following the intravenous injection of a contrast agent, is considered to be the gold standard diagnostic test for DVT. However, because of its invasiveness and risk of thrombosis it has largely been replaced by ultrasonography, which has an average sensitivity and specificity of 97% for detecting DVT in the thigh but a somewhat lower sensitivity for detecting calf DVT (approximately 75%).44

### NEUROLOGICAL ASSESSMENT

Lower limb neurological assessment in older people can be challenging, as it is often difficult to distinguish between observations of normal age-related changes and those related to a neuropathic process. The initial assessment interview and history taking may provide useful insights into conditions commonly associated with neuropathy, such as diabetes, chronic alcoholism, vitamin B₁₂ deficiency and the side effects of certain medications. However, self-reported ‘numbness of the feet’ cannot be relied upon as an indicator of sensory loss, as it has been shown to be a poor predictor of electrodiagnostically-confirmed neuropathy in older people.45

A wide range of clinical tests, such as tactile sensitivity testing with graded monofilaments, two-point discrimination, vibration sense (with tuning forks or neurothesiometers), temperature perception, pain detection, proprioception and lower limb reflexes are commonly used to detect lower limb sensory loss (Table 3.10). Although these tests are widely used,

---

**Table 3.9 Clinical prediction rule for the diagnosis of deep vein thrombosis (DVT)**

<table>
<thead>
<tr>
<th>Clinical features</th>
<th>Major points</th>
<th>Minor points</th>
<th>Clinical probability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Active cancer</td>
<td>History of recent trauma (≥60 days) to the symptomatic leg</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>Paralysis, paresis or recent plaster immobilisation of the lower limb</td>
<td>Pitting oedema: symptomatic leg only</td>
<td>≥3 major points and no alternative diagnosis</td>
</tr>
<tr>
<td></td>
<td>Recently bedridden &gt;3 days and/or major surgery within 4 weeks</td>
<td>Dilated superficial veins (non-varicose) in symptomatic leg only</td>
<td>≥2 major points and ≥2 minor points and no alternative diagnosis</td>
</tr>
<tr>
<td></td>
<td>Localised tenderness along the distribution of the deep venous system</td>
<td>Hospitalisation within previous 6 months</td>
<td>1 major point + ≥2 minor points and has an alternative diagnosis</td>
</tr>
<tr>
<td></td>
<td>Thigh and calf swollen</td>
<td>Erythema</td>
<td>0 major points + ≥3 minor points and has an alternative diagnosis</td>
</tr>
<tr>
<td></td>
<td>Calf swelling 3 cm asymptomatic side (measured 10 cm below tibial tuberosity)</td>
<td></td>
<td>0 major points + ≥2 minor points and no alternative diagnosis</td>
</tr>
<tr>
<td></td>
<td>Strong family history of DVT (≥2 first-degree relatives with history of DVT)</td>
<td></td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>All other combinations</td>
</tr>
</tbody>
</table>

---
few have been adequately examined for validity in older people. Furthermore, the use of ankle reflex testing or tuning forks alone to detect neurological problems is confounded by the fact that over one-third of people aged over 70 years do not appear to have an ankle reflex and a similar proportion cannot detect vibratory stimuli at the ankle. Therefore, commonly employed clinical tests applied in isolation may not provide the same level of diagnostic accuracy when applied to older people.

To address this issue, Richardson recently developed a clinical screening approach incorporating a range of clinical tests in 100 older people and correlated these findings with electrodiagnostic tests of peripheral polyneuropathy. The results indicated that all clinical tests differentiated between older people with and without electrodiagnostically confirmed neuropathy; however, the best prediction of neuropathy was provided by using a combination of three tests: the Achilles reflex, vibration sense at the toe and position sense at the toe. Having two or three abnormal signs demonstrated a sensitivity of 91% and specificity of 93% for neuropathy (Table 3.11). Interestingly, the diagnostic accuracy of this protocol was not greatly affected by whether or not the participants had diabetes, indicating that it may have broad application for the detection of neuropathy resulting from a range of conditions.

Table 3.10 Clinical screening tests of lower limb sensory function

<table>
<thead>
<tr>
<th>Test</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tactile sensitivity</td>
<td>Cotton wool lightly stroked on the foot while patient has eyes closed. Patient is asked to report which foot is being stroked and the site</td>
</tr>
<tr>
<td>Two-point discrimination</td>
<td>Specially constructed devices with tips separated by varying distances are applied to the foot while patient has eyes closed. Patient is asked to report how many points can be felt (i.e. one or two)</td>
</tr>
<tr>
<td>Pressure perception</td>
<td>Flexible plastic filaments of varying thickness are applied to the foot while patient has eyes closed, and threshold detection level is documented. A commonly employed cut-off is the 10 g filament</td>
</tr>
<tr>
<td>Vibration sense</td>
<td>Three methods: 1. 128 Hz tuning fork 2. Graduated Rydel-Seiffer tuning fork 3. Neurothesiometer  For each method, vibration sense is determined by applying the vibration to a bony prominence (apex of the hallux, first metatarsophalangeal joint or malleoli) while patient has eyes closed. Patient is asked to report any perceived sensation. The 128 Hz tuning fork produces a dichotomous test result (i.e. vibration sense is present or absent), the graduated tuning fork is semi-quantitative and the neurothesiometer produces a continuous score in volts, with values over 25 indicating neuropathy</td>
</tr>
<tr>
<td>Temperature perception</td>
<td>Two test-tubes filled with cold (&lt;30°C) and hot water (&gt;35°C) are applied to the foot while patient has eyes closed. Patient is asked to state which tube they find cooler/warmer</td>
</tr>
<tr>
<td>Pain</td>
<td>Disposable sharp and blunt rods (such as Neurotips) are randomly applied to the foot while patient has eyes closed. Patient is asked to report which is the sharper rod</td>
</tr>
<tr>
<td>Proprioception</td>
<td>Dominant hallux grasped on medial and lateral surfaces by thumb and forefinger. Small amplitude up and down movements randomly administered, with patient asked to report direction of movement</td>
</tr>
<tr>
<td>Ankle reflex</td>
<td>Achilles tendon is struck with a reflex hammer while the foot is lightly dorsiflexed; plantarflexion response is detected with the other hand</td>
</tr>
</tbody>
</table>
MUSCULOSKELETAL ASSESSMENT

Foot deformity

The prevalence of foot deformity increases markedly with age, because of the combined effects of musculoskeletal changes and the detrimental effects of footwear. As discussed in Chapter 1, the most common foot deformities in older people – hallux valgus and lesser toe deformities – are often associated with the development of hyperkeratosis and forefoot pain and have a significant detrimental impact on balance and functional ability. Hallux valgus can be easily graded in the clinical environment using the Manchester scale, which consists of four standardised photos covering the spectrum of the deformity (Fig. 3.6). A recent study by Menz & Munteanu showed that gradings using this scale were significantly associated with hallux abductus and intermetatarsal angles obtained from foot radiographs. Lesser toe deformities (hammer toes, claw toes, mallet toes and retracted toes) can be simply evaluated by assessing the position and range of motion of the metatarsophalangeal, proximal and distal interphalangeal joints. Each of these conditions is described in detail in Chapter 8.

The length of each of the metatarsals, often referred to as metatarsal formula, is a useful assessment to undertake in older people, as excessively long or short metatarsals have been associated with the development of hallux valgus, hallux limitus and plantar keratotic lesions. In the normal foot, the second metatarsal is usually the longest and the fifth is the shortest, resulting in a metatarsal formula of $2 > 1 > 3 > 4 > 5$, $2 > 3 = 1 > 4 > 5$ or $2 > 3 > 1 > 4 > 5$. Palpation and marking of the plantar metatarsal

<table>
<thead>
<tr>
<th>Test</th>
<th>Description</th>
<th>Cut-off score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Achilles reflex</td>
<td>Achilles tendon is struck with a reflex hammer while the foot is lightly dorsiflexed</td>
<td>Absent plantarflexion response</td>
</tr>
<tr>
<td>Vibration sense</td>
<td>128 Hz tuning fork applied just proximal to the nailbed of the hallux, and time taken until patient reports that the vibration has disappeared is recorded in seconds</td>
<td>$&lt; 8$ s</td>
</tr>
<tr>
<td>Position sense</td>
<td>Dominant hallux grasped on medial and lateral surfaces by thumb and forefinger. 10 small-amplitude up and down movements randomly administered, with patient asked to report direction of movement</td>
<td>$&lt; 8/10$ correct responses</td>
</tr>
</tbody>
</table>

Table 3.11 Clinical screening approach for the detection of neuropathy in older people

<table>
<thead>
<tr>
<th>Test</th>
<th>Description</th>
<th>Cut-off score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Achilles reflex</td>
<td>Achilles tendon is struck with a reflex hammer while the foot is lightly dorsiflexed</td>
<td>Absent plantarflexion response</td>
</tr>
<tr>
<td>Vibration sense</td>
<td>128 Hz tuning fork applied just proximal to the nailbed of the hallux, and time taken until patient reports that the vibration has disappeared is recorded in seconds</td>
<td>$&lt; 8$ s</td>
</tr>
<tr>
<td>Position sense</td>
<td>Dominant hallux grasped on medial and lateral surfaces by thumb and forefinger. 10 small-amplitude up and down movements randomly administered, with patient asked to report direction of movement</td>
<td>$&lt; 8/10$ correct responses</td>
</tr>
</tbody>
</table>

Figure 3.6 Manchester scale for grading hallux valgus severity. A. No hallux valgus. B. Mild. C. Moderate. D. Severe. (With permission from Garrow AP, Papageorgiou A, Silman AJ et al. The grading of hallux valgus. The Manchester Scale. Journal of the American Podiatric Medical Association 2001; 91: 74–78.50)
heads while the corresponding toe is maximally dorsiflexed has been shown to be a valid indicator of metatarsal formula determined from dorsoplantar foot X-rays.52

The prevalence and clinical significance of the forefoot and rearfoot malalignments described by Root et al53 (including forefoot varus, valgus and supinatus, plantarflexed and dorsiflexed first ray, and rearfoot varus and valgus) have been comprehensively debated in recent years. Some doubt has been raised in relation to whether these conditions actually exist, whether they can be accurately measured and whether they have a predictable impact on dynamic foot function.54 In the absence of compelling evidence that these observations influence foot function or predisposition to foot problems in older people, it is my view that a standard geriatric foot and ankle assessment should instead focus on obvious deformities that can be clearly recognised and documented.

**Foot posture**

Despite the proposed relationships between foot posture and the development of overuse conditions affecting the lower limb, there is still considerable disagreement regarding how best to assess and classify foot posture.55 A wide range of tests have been proposed, including structured visual observation,56–58 various footprint parameters,59,60 measurement of frontal plane heel position61,62 and assessment of the position of the navicular tuberosity.63 Very few of these tests have undergone rigorous validation. To address this issue, Menz & Munteanu64 recently compared three clinical tests of foot posture (the arch index, navicular height and the Foot Posture Index) with arch-related measurements obtained from lateral foot X-rays in 95 older people. The results indicated that all three tests were significantly correlated with radiographic measurements, with the strongest associations found for navicular height and the arch index. A subsequent study involving plantar pressure measurements indicated that the arch index is a significant predictor of forces under the midfoot during walking,65 suggesting that this technique may be a useful clinical assessment to perform in older patients.

To determine the arch index, a static footprint is obtained using an ink or carbon-paper imprint system, and the area of the middle third of the footprint is divided by the total area of the footprint (ignoring the toes). This is shown in Figure 3.7. A higher arch index represents a flatter foot. Because the calculation of the arch index can be time-consuming, a simple classification of high, normal and flat based on a visual observation of the print may be more feasible for routine clinical use. Representative footprints obtained from a sample of 292 people aged between 65 and 96, along with their arch index ranges, are shown in Figure 3.8.

The Foot Posture Index (FPI) is also worthy of consideration as a foot screening tool.58 The FPI involves visual rating of six criteria: palpation of the talar head, observation of supra/infra malleolar curvature, inversion/eversion of the calcaneus, medial prominence of the talonavicular joint, congruence of the medial arch and abduction/adduction of the forefoot on the rearfoot. Each of these criteria is scored on a 5-point scale (range -2 to +2) and the summed score provides a single index of the degree of the pronated/supinated posture of the foot, with higher scores representing a more pronated (flatter) foot. The FPI has moderate to good reliability and FPI scores have been found to correlate with the frontal plane position of the ankle joint complex during the midstance phase of gait.58 FPI scores have been shown to be significantly higher in older people than younger people (a mean of 4.4 compared to 2.5), which may indicate an age-related flattening of the medial longitudinal arch.49
Range of motion

Assessing the available motion in the foot is a standard and necessary component of the lower limb assessment. Preferred techniques for assessing joint range of motion in the foot are shown in Figure 3.9. Unfortunately, the reliability of range of motion assessments in the foot is somewhat questionable (particularly between clinicians), as the absolute ranges of motion are small and the contribution of skin movement error is considerable. Nevertheless, although precise quantification is not possible, broad classification of foot joint motion as normal, hypermobile or restricted is probably sufficient for clinical decision making. In older people, two joints are of particular importance – the first metatarsophalangeal joint and the ankle joint – as these joints provide the main sagittal plane pivots during propulsion, and both joints undergo significant reductions in motion with advancing age.49 First metatarsophalangeal joint dorsiflexion (assessed in a non-weightbearing position – Fig. 3.9A) is

Figure 3.8 Simple visual categorisation of the arch index.

Figure 3.9 Assessment of joint range of motion in the foot. A. First metatarsophalangeal joint. B. Ankle joint dorsiflexion. C. Ankle joint complex inversion/eversion.
significantly correlated with the loading of the first ray during gait, and restricted motion in this joint is associated with impaired balance. In older people, the normal value for this test is approximately 55° (compared to approximately 80° in younger people).

Although there are several methods of assessing the range of motion of the ankle joint, the weightbearing lunge test provides a functionally relevant indicator of available ankle dorsiflexion and has been shown to be reliable and related to balance and functional ability in older people. To perform the test, the lateral malleolus and head of the fibula are located and marked with a pen. The patient is then asked to stand with their foot placed alongside a vertically aligned clear acrylic plate inscribed with 2° protractor markings and instructed to take a comfortable step forward with the contralateral leg. In this position, the patient is requested to bend their knees to squat down as low as possible, without lifting the right heel from the ground and while keeping the trunk upright. The position of the fibular head is marked on the clear acrylic plate, and the angle formed between the lateral malleolus and the fibular head is measured (Fig. 3.9B). The normal range of motion when performing this test is approximately 30–50°, with smaller values being associated with impaired balance and functional ability and an increased risk of falls. In the absence of the acrylic plate apparatus, similar measurements can be obtained by placing a gravity angle finder on the tibia while the patient assumes the lunge position.

The complex triplanar movements that occur at the ankle, subtalar and midtarsal joints are particularly difficult to quantify and several studies have reported low levels of reliability for frontal plane measurements of subtalar joint range of motion. Recently, however, Menadue et al reported high levels of test–retest reliability for inversion/eversion range of motion measurements conducted with the patient in a seated position using a flexible goniometer (Fig. 3.9C). Because the ankle is placed in a comfortable planatarflexed position and the distal arm of the goniometer is placed on the dorsum of the foot, measurements obtained from this technique represent triplanar motion of the ankle–subtalar complex rather than ankle inversion/eversion per se. Mean values obtained from 30 young participants were reported to be 32° of inversion and 10° of eversion. Midtarsal joint motion is virtually impossible to quantify; however, useful insights may be obtained by stabilising the subtalar joint with one hand while moving the midtarsal joint through its full range of inversion/eversion, dorsiflexion/adduction and plantarflexion/abduction. Notable restriction in joint range of motion will be particularly evident in older people with midfoot osteoarthritis.

### Strength testing

Manual muscle testing of the foot and ankle can provide useful insights into strength deficits in older people. The basic principle of manual muscle testing is to adequately stabilise the body part proximal to the muscle being tested and to apply firm pressure directly opposite the line of pull of the muscle. Descriptions of hand placement and force application are shown in Table 3.12 and Figure 3.10. The simple grading system initially proposed by Kendall & Kendall is then applied (Table 3.13). Although there is some subjectivity involved in this grading system (and care needs to be taken when comparing findings between clinicians), it has been demonstrated that foot and ankle muscle testing observations are related to the intensity of muscle activity during gait.

Another useful clinical muscle test is the paper grip test, which was first developed to assess muscle paralysis in the feet of leprosy patients. To perform the test, the patient is seated with their hip, knee and ankle at 90° and is instructed to use their toe muscles to push down on a 280 gsm piece of cardboard while the clinician stabilises the ankle and forefoot and attempts to slide the cardboard away from the toes (Fig. 3.11). The test is performed three times for the halluc and lesser toes individually and is documented as a pass if the patient can hold the cardboard for all attempts to slide the cardboard away from the toes (Fig. 3.11). The test is performed three times for the halluc and lesser toes individually and is documented as a pass if the patient can hold the cardboard for all three trials, and a fail if they fail to grip the cardboard on at least one trial. Menz et al have recently shown that significant age-related changes exist in toe plantarflexor strength, and that the paper grip test is an accurate predictor of strength measurements obtained from a plantar pressure platform. Toe plantarflexor strength has also been shown to be correlated with the magnitude of pressure borne by the toes during gait and weakness of the toes is associated with impaired balance and falls in older people.

The precision of manual muscle testing can be improved with the use of hand-held dynamometers. These devices contain a strain gauge and consist of a handle and a flat surface, which is placed against the area being tested. Using the same principles as
### Table 3.12 Manual muscle testing procedures

<table>
<thead>
<tr>
<th>Motion</th>
<th>Positioning of patient</th>
<th>Stabilising hand placement</th>
<th>Resistance hand placement</th>
<th>Instruction to patient</th>
<th>Muscles tested</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ankle dorsiflexion</td>
<td>Seated, leg extended off table</td>
<td>Distal posterior tibia</td>
<td>Dorsomedial surface of the foot</td>
<td>Dorsiflex and invert the foot by bringing toe towards shin</td>
<td>Tibialis anterior</td>
</tr>
<tr>
<td>Ankle plantarflexion</td>
<td>Seated, foot and leg extended off table</td>
<td>Distal anterior tibia</td>
<td>Plantar surface of the foot</td>
<td>With knee extended (gastrocnemius) and flexed &gt;45° (soleus) point foot against resistance</td>
<td>Gastrocnemius, soleus</td>
</tr>
<tr>
<td>Ankle plantarflexion</td>
<td>Standing on one leg using hand on table for balance</td>
<td>None</td>
<td>None</td>
<td>Raise heel 20 times, or until unable to complete full motion</td>
<td>Gastrocnemius, soleus</td>
</tr>
<tr>
<td>Inversion</td>
<td>Lying on side to be tested, foot slightly plantarflexed</td>
<td>Distal medial tibia</td>
<td>Medial aspect of foot</td>
<td>Raise medial border of foot toward ceiling</td>
<td>Tibialis posterior</td>
</tr>
<tr>
<td>Eversion</td>
<td>Lying on side not being tested, foot slightly plantarflexed</td>
<td>Distal lateral tibia</td>
<td>Lateral aspect of foot</td>
<td>Raise lateral border of foot toward ceiling</td>
<td>Peroneus longus and brevis</td>
</tr>
<tr>
<td>2nd–5th MTP and IP toe flexion</td>
<td>Supine, foot resting on table</td>
<td>MTP: Metatarsal PIP: Proximal phalanx DIP: Middle phalanx</td>
<td>MTP: Proximal phalanx PIP: Middle phalanx DIP: Distal phalanx</td>
<td>Flex or curl toes</td>
<td>MTP: Lumbricals PIP: Flexor digitorum brevis DIP: Flexor digitorum longus</td>
</tr>
<tr>
<td>2nd–5th MTP and IP toe extension</td>
<td>Supine, foot resting on table</td>
<td>Metatarsals</td>
<td>Distal phalanx</td>
<td>Extend toes</td>
<td>Extensor digitorum longus and brevis</td>
</tr>
<tr>
<td>Hallux flexion</td>
<td>Supine, foot resting on table</td>
<td>MTP: 1st metatarsal</td>
<td>MTP: Proximal phalanx</td>
<td>Flex big toe</td>
<td>MTP: Flexor hallucis brevis IP: Flexor hallucis longus</td>
</tr>
<tr>
<td>Hallux extension</td>
<td>Supine, foot resting on table</td>
<td>1st metatarsal</td>
<td>Proximal and distal phalanx</td>
<td>Extend big toe</td>
<td>Extensor hallucis brevis (PIP) and longus (DIP)</td>
</tr>
</tbody>
</table>

IP, interphalangeal joint; DIP, distal interphalangeal joint; MTP, metatarsophalangeal joint; PIP, proximal interphalangeal joint.
described in Table 3.11, the maximum force generated by the body part is recorded in kilograms or Newtons. While intratester reliability of dynamometry is very high, intertester reliability is only moderate, as the scores are affected by variations in technique and the strength of the clinician.\textsuperscript{75} The test–retest reliability of hand-held dynamometry for foot muscles was recently evaluated by Burns et al,\textsuperscript{76} who indicated that the reliability of foot inversion/eversion and plantarflexion/dorsiflexion measurements was excellent, with standard errors of measurement ranging between 0.3 and 0.7 kg.
DIAGNOSTIC IMAGING

Generally speaking, most common foot problems affecting older people can be adequately diagnosed from information obtained from the medical history, initial assessment interview and physical examination. However, several diagnostic imaging techniques can greatly assist in the diagnosis of a wide range of osseous and soft tissue pathologies that may develop in older people. Access to these modalities varies considerably between professions and between countries, so many foot-care specialists will find it necessary to establish referral systems with medical specialists who have a greater scope of practice in this area. The role of diagnostic imaging for specific pathologies is discussed in subsequent chapters; however, the following section briefly outlines the structures that can be visualised with each modality.

<table>
<thead>
<tr>
<th>Grade</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 – Normal</td>
<td>Resists strong pressure</td>
</tr>
<tr>
<td>3 – Good</td>
<td>Resists moderate pressure</td>
</tr>
<tr>
<td>2 – Fair</td>
<td>Resists gravity through full range of motion</td>
</tr>
<tr>
<td>1 – Poor</td>
<td>Resists gravity through partial range of motion</td>
</tr>
<tr>
<td>0 – None</td>
<td>No muscle activity</td>
</tr>
</tbody>
</table>

**Table 3.13 Manual muscle testing grades**

Plain film radiography (X-ray) is the most common used imaging modality for assessing musculoskeletal foot problems in older people. Radiography is relatively inexpensive, has a quick turnaround time and can generate very high-quality images with only minimal radiation exposure.\(^77\) The standard foot series generally includes a dorsoplantar projection and lateral projection, taken either non-weightbearing or weightbearing. Weightbearing radiographs are preferable to non-weightbearing radiographs, as the foot is captured in a more functional position, which enables representative postural measurements (such as arch height) to be obtained. The dorsoplantar projection provides a clear image of the midfoot and forefoot; however, the talus and calcaneus may be obscured by the distal end of the tibia and fibula. The lateral projection clearly depicts the talus, calcaneus and medial column of the foot; however, the superimposition of midfoot and metatarsal bones may make it difficult to clearly view the lateral structures. A range of other projections may be ordered to specifically target localised pathologies such as sesamoid disorders and subungual exostoses.

Features that can be readily observed from standard foot radiographs include overall bone density (as evidenced by generalised radiolucency), calcaneal and Achilles tendon spurs, accessory bones, metatarsal length variations, angular deformities (such as hallux valgus), arch height and osteoarthritic changes (such as joint space narrowing, osteophytes, sclerosis and subchondral cysts). Although very little soft tissue is evident on plain film radiographs, it is not uncommon to observe thread-like calcifications of the dorsalis pedis artery in X-rays obtained from older people, particularly those with diabetes.\(^78\)

When assessing foot radiographs of older people, it is necessary to keep in mind that some apparently abnormal features are so common in this age group that they can be considered normal age-related changes. Such features include plantar calcaneal spurs, osseous irregularities in the ungual tuberosity of the distal phalanges (which may mimic psoriatic arthritis), enlargements of the base of the proximal phalanx due to spurring of the lateral interosseous ligaments, and localised loss of bone density in the proximal phalanx of the hallux, medial aspects of the first and fifth metatarsal heads and the navicular.\(^78\) When examining dorsoplantar radiographs, it also needs to be kept in mind that clawing of the digits may give a misleading appearance of an abnormal condition.

**Figure 3.11** The paper grip test. **A.** Hallux. **B.** Lesser toes.
impression of joint space narrowing due to superimposition of the phalanges.

**BONE SCANNING**

Bone scanning involves the intravenous injection of a radioactive isotope (most commonly, technetium-99), which becomes distributed in the bloodstream and is ultimately taken up by the tissues. In the presence of bone pathology, the increased blood flow and corresponding increase in osteoblastic activity in the affected region causes an accumulation of the isotope. By converting this radioactivity into a visual image, areas of increased uptake can be easily identified. Bone scans are particularly useful for the identification of stress fractures, bone tumours and Paget’s disease.

The main indication for bone scanning of the foot in older people is insufficiency fracture, which most commonly affects the metatarsals but may also develop in the talus and calcaneus and may not be visible on plain film X-ray. Bone scanning has a much higher sensitivity for detecting osseous changes, as it reflects bone metabolism rather than structure. However, bone scanning has a very low specificity, which increases the likelihood of false-positive findings. In particular, there appears to be a high rate of false-positive results for foot scans. A study of 60 patients with foot pain and 30 asymptomatic controls by O’Duffy et al reported that 24 of the controls demonstrated focal areas of increased uptake, most commonly in the metatarsophalangeal joints, the midfoot and the plantar aspect of the calcaneus.

**ULTRASONOGRAPHY**

Diagnostic ultrasound involves the generation of very-high-frequency sound waves that are transmitted through a coupling gel to the body part being examined. Depending on the density of the target tissue, these sound waves are reflected in varying velocity and wavelength and the aggregation of this information is then used to construct a two-dimensional image of the underlying tissue. Ultrasound can capture high-resolution images of muscle, tendons, ligaments and soft tissue masses in real time, at relatively low cost. However, perhaps more than any other imaging technique, ultrasound is highly operator-dependent and requires considerable practice to become proficient. Foot conditions that may be detected with ultrasound include tendon pathology, synovial effusions, ligament rupture, plantar fascial thickening, ganglia, bursitis, Morton’s neuroma and various soft tissue neoplasms. Ultrasound may also be used to assist in the accurate guidance of corticosteroid injections for conditions such as plantar fasciitis and retrocalcaneal bursitis.

**COMPUTED TOMOGRAPHY**

The basic principle of computed tomography (CT) is to irradiate a slice of tissue from multiple angles and measure the output from the opposite side, which varies depending on the density of the target tissue. This output is then mapped according to predetermined tissue-specific attenuation cut-off values and a greyscale image is generated, with each shade of grey representing a different tissue type. The first CT scanners were only capable of generating an image derived from a single slice; however, recent advances in computer technology have enabled multiple slices to be acquired, which can then be rendered into three-dimensional images. Unfortunately, the more slices obtained, the greater the dose of radiation the patient is exposed to, so the clinician needs to carefully consider whether high-resolution images are necessary to reach a diagnosis. CT has a relatively limited role in the diagnosis of foot conditions, although it may be useful in the examination of bony tumours, complex fractures and chronic osteomyelitis.

**MAGNETIC RESONANCE IMAGING**

Magnetic resonance imaging (MRI) involves the application of radiofrequency pulses to the body that match the resonant frequency of the body’s hydrogen atoms. The hydrogen atoms then re-emit this energy as a magnetic resonance signal, which is detected as a voltage by a receiver coil. The subsequent ‘relaxation times’ of the hydrogen atoms vary across different tissue types, which enables the construction of high-spatial-resolution images of soft tissue, cartilage and bone. MRI is a useful imaging modality for several foot pathologies, including osteochondral lesions, stress fractures, tendon rupture, plantar fasciitis, plantar plate rupture, Morton’s neuroma and osteomyelitis. Unfortunately, the high cost of MRI scans precludes their wider application in the diagnosis of foot problems.
FUNCTIONAL ASSESSMENT

The ability to perform routine activities such as dressing, performing housework and shopping are key components of an older person’s independence and quality of life. As stated in the introduction, there is now considerable evidence that foot problems have a significant detrimental impact on these abilities. Clinical assessment of an older person’s functional ability and mobility is therefore an integral component of geriatric assessment, not only to determine the baseline status of the older patient but also as a way of measuring the effectiveness of interventions.

ACTIVITIES OF DAILY LIVING

Activities of daily living can be broadly categorised as: (1) basic activities of daily living (BADLs), (2) instrumental activities of daily living (IADLs) and (3) advanced activities of daily living (AADLs). BADLs are considered necessary but not sufficient for maintaining independence, IADLs are necessary to maintain an independent household environment and AADLs are complex tasks requiring high levels of physical and cognitive functioning. Assessment of functional status is relatively straightforward and may simply require a brief checklist to be completed by the patient as part of the consultation. Several validated tools have also been developed, including the Barthel index, which consists of 10 questions relating to bowel continence, bladder continence, grooming, toilet use, feeding, transfers, mobility, dressing, stair climbing and bathing. These scales are able to predict functional decline, institutionalisation and mortality in older people; however, they are generally not sensitive enough to detect short-term changes in relatively highly functioning older people.

OBJECTIVE MEASURES OF MOBILITY

Objective measures of gait and mobility, such as walking speed and rising from a chair, are also useful tools for assessing functional status and are sensitive enough to be used as clinical outcome measures. Walking speed, which can be simply measured with a stopwatch over a set distance, provides an indicator of not only lower limb muscle strength but also balance, reaction time and psychological status. Prospective studies have also shown that walking speed is a strong predictor of institutionalisation and mortality in older people. Similarly, measuring the time taken to rise from a chair five times (the sit-to-stand test) provides an overall measure of physical ability and can identify older people at risk of falling. Both walking speed and sit-to-stand have been shown to be impaired in older people with foot problems. Some objective tests of mobility are also accurate predictors of falls (see section on falls risk assessment).

EVALUATION OF GAIT DISORDERS

At least 20% of older people report difficulty walking or require assistance with gait-related tasks. Although a small reduction in walking speed and step length appears to be a normal consequence of ageing, there is increasing evidence that most other gait changes frequently observed in older people are the result of underlying conditions that increase in prevalence with advancing age, such as osteoarthritis, stroke, peripheral neuropathy and dementia. In many older people with a gait problem, more than one potential contributing condition is present, which can make accurate diagnosis difficult.

Classifying gait disorders

Alexander & Goldberg have proposed a classification of gait disorders according to the level of the sensorimotor system they primarily affect. Low-level gait disorders are those that influence structures distal to the central nervous system, including peripheral sensory impairments (such as peripheral neuropathy, vestibular disorders and visual problems) and peripheral motor impairments (such as arthritic and myopathic conditions). Middle level gait disorders include those resulting from spasticity (such as myelopathy, vitamin B12 deficiency and stroke), parkinsonism (idiopathic or drug-induced) and cerebellar ataxia (resulting from alcohol abuse). High level gait disorders include cautious gait (resulting from behavioural adaptations due to fear of falling) and those related to frontal lobe problems (such as stroke affecting the cortex or basal ganglia). A summary of these disorders, including their characteristic gait changes and associated physical findings, is shown in Table 3.14. Although this system provides a useful clinical summary of gait changes associated with specific conditions, there is often considerable overlap in their presentation.
Table 3.14 Classification of common gait disorders in older people

<table>
<thead>
<tr>
<th>Level</th>
<th>Classification</th>
<th>Condition</th>
<th>Gait characteristics</th>
<th>Associated physical findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Peripheral sensory</td>
<td>Sensory ataxia</td>
<td>Steppage gait</td>
<td>Loss of tactile sensitivity and proprioception</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Vestibular ataxia</td>
<td>Weaving from side to side May fall to one side</td>
<td>Nystagmus</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Visual ataxia</td>
<td>Tentative, cautious</td>
<td>Visually impaired</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Arthritic</td>
<td>Shortened stance phase on affected side</td>
<td>Avoidance of weightbearing on affected side</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Trendelenburg sign</td>
<td>Limited knee flexion</td>
</tr>
<tr>
<td></td>
<td>Peripheral motor</td>
<td></td>
<td></td>
<td>Decreased lumbar lordosis</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Stooped posture</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Myopathic and neuropathic – proximal</td>
<td>Exaggerated lumbar lordosis Trendelenburg sign</td>
<td>Kyphosis</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Weakness of hip musculature</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Myopathic and neuropathic – distal</td>
<td>Waddling gait Foot slapping</td>
<td>Weakness of ankle dorsiflexors</td>
</tr>
<tr>
<td></td>
<td>Middle</td>
<td>Spasticity</td>
<td>Leg circumduction</td>
<td>Leg weakness/spasticity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hemiplegia/paresis</td>
<td>Loss of arm swing Foot dragging</td>
<td>Knee hyperextension</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Paraplegia/paresis</td>
<td>Bilateral leg circumduction Scissor gait Small shuffling steps</td>
<td>Ankle equinovarus</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Parkinsonism</td>
<td>Absent arm swing Freezing</td>
<td>Arm weakness/spasticity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cerebellar ataxia</td>
<td>Wide base of gait Increased trunk sway</td>
<td>Leg weakness/spasticity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Staggering</td>
<td></td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>Cautious gait</td>
<td>Wide base of gait Shortened stride Decreased velocity</td>
<td>Fear of falling</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cerebrovascular disorders</td>
<td>Wide base of gait Shortened stride Decreased velocity Difficulty initiating gait Freezing</td>
<td>Atherosclerotic disease Cognitive impairment Leg weakness/spasticity Incontinence</td>
</tr>
</tbody>
</table>

**Clinical gait analysis**

The clinical assessment of gait disorders involves a thorough systems examination in addition to the direct observation of movement patterns. Gait analysis techniques range from simple visual observation through to high-tech instrumented gait analysis procedures. For the foot-care specialist, visual observation of gait features shown in Table 3.14, including documentation of temporospatial parameters such as velocity, cadence and step length, is probably a sufficient basis upon which to determine whether a referral is required for further diagnostic evaluation. In the clinical setting, all this requires is sufficient space to conduct a brief gait assessment (preferably at least
Walking. Furthermore, some older people may find patterns on a treadmill may differ from normal overground sufficient training in applying the technique. 111 Plantar pressures, provided that clinicians undergo paper prints provide a sensitive measure of peak an optical pedobarograph indicated that the carbon be documented in a quantitative manner. A study using a calibration card, the pressure recording can record varying levels of grey when pressure is applied. A similar low-cost system uses carbon paper sheets, which densely inked because of the compression of the mat to the lower level of ridges. The Harris & Beath mat is a very useful clinical tool for documenting foot shape and identifying high pressure areas; however, the data obtained from the system can only be considered to be semi-quantitative, despite attempts to calibrate the outputs to known forces. 110 A similar low-cost system uses carbon paper sheets, which record varying levels of grey when pressure is applied. Using a calibration card, the pressure recording can be documented in a quantitative manner. A study comparing pressures obtained using this technique to an optical pedobarograph indicated that the carbon paper prints provide a sensitive measure of peak plantar pressures, provided that clinicians undergo sufficient training in applying the technique. 111

More recently, several plantar pressure systems based on resistive or capacitive sensor technology have become commercially available, either as platform-based systems or in the form of insoles placed inside the shoe. 112 Although the cost of many of these systems currently limits their use to the research environment, scaled-down versions with lower sampling frequencies and sensor resolution are likely to become more widely adopted in clinical practice in years to come. The major benefit of these systems over simple footprinting techniques is that their outputs are truly quantitative, and various force, pressure and timing parameters obtained from the pressure recording can be documented.

When undertaking such assessments, however, it needs to be kept in mind that the pressure distribution under the foot is dependent on a wide range of factors, including walking speed, step length, bodyweight, foot deformity and the degree of peripheral sensory loss. 65 Because of this complexity, extrapolating foot motion characteristics (such as the degree of foot pronation) from plantar pressure recordings is difficult. While it appears that foot pronation does result in greater medial loading of the midfoot in older people, forefoot pressures are more closely correlated to the degree of hallux valgus deformity and the available range of motion in the first metatarsophalangeal joint. 55 Examples of foot pressure recordings from older people are shown in Figure 3.12 and a summary of the strongest clinical predictors of plantar forces in older people in Figure 3.13.

### FALLS RISK ASSESSMENT

Community-based studies indicate that one in three people aged over 65 years will fall in any given year. Falls frequently result in injury and are the leading cause of injury-related death in older people. 113 The role and scope of podiatry in falls prevention is poorly defined but is gaining considerable attention in response to recent studies indicating that foot problems (including foot pain, hallux valgus, decreased ankle flexibility, peripheral sensory loss and toe plantarflexor weakness) are independent risk factors for falling. 68 Given these observations, it is likely that most older people attending foot-care specialists have an elevated risk of falling compared to the general elderly population. However, documenting medical conditions that are strong risk factors for falling and undertaking some simple clinical tests will provide more accurate identification of very-high-risk older people who are most likely to benefit from falls prevention activities. Table 3.15 describes some simple tests that have been shown to be useful predictors of falls. 114–117 Footwear evaluation also plays a role in falls risk assessment (see Footwear assessment, below).
ASSESSMENT OF THE ABILITY TO PERFORM BASIC FOOT CARE

Many clinical interventions require the patient to undertake some level of self-management of their foot problem in the household environment. For this reason, foot specialists need to be aware of the ability of older patients to maintain adequate foot hygiene and undertake basic foot-care tasks, such as cutting and filing nails, applying emollient creams, washing and drying feet, managing areas of dry skin and calluses, putting on shoes and hosiery, inspecting the foot for lesions and changing wound dressings. Failure to adequately assess an older person’s competence to perform these tasks can have serious ramifications, particularly in older people with peripheral vascular disease or diabetes.

Undertaking basic foot care is inherently difficult for older people, as it requires not only adequate joint flexibility but also a high level of manual dexterity and visual acuity, all of which decline with advancing age. A particularly good example of the importance of assessing basic foot-care competence was provided by Thomson & Masson,118 who evaluated the ability of older people with and without diabetes to reach down to their feet to inspect a ‘virtual lesion’ – an adhesive red spot placed on the toes or on the plantar surface of the foot. The results indicated that 39% of those with diabetes could not reach their toes, and only 14% of all older participants could detect the plantar ‘lesion’. It is therefore clear that advising older people to undertake basic foot-care tasks is not helpful unless they are actually capable of performing the task.

Evaluating self-management ability can be undertaken during a routine consultation by simply observing whether the patient is capable of removing their footwear and whether they have sufficient flexibility to reach and indicate the location of the foot problem. Assessing other aspects of self-management, such as using nail files, changing dressings and applying emollients, may require the clinician to specifically request

Figure 3.13 Determinants of plantar forces in older people. Values displayed in mask regions represent $r^2$ values, and values contained in brackets represent $\beta$-weights for each significant independent ('predictor') variable. *significance of $\beta$-weight $p < 0.05$, **significance of $\beta$-weight $p < 0.01$. MPJ, metatarsophalangeal joint; ROM, range of movement.

Figure 3.12 Examples of foot pressure recordings from older people. A. Hallux limitus. B. Tibialis posterior dysfunction. C. Severe hallux valgus deformity and associated plantar lesions. D. Pes cavus foot type.
that the patient demonstrate these skills. Assistive
devices (such as long-handled shoe horns, nail files
and devices to assist with footwear fixation) should
also be available and demonstrations provided to
patients who may benefit from them.

**FOOTWEAR ASSESSMENT**

Evaluation of footwear is one of the most fundamen-
tal components of lower limb assessment in older
people. It has been demonstrated that between 50
and 80% of older people wear ill-fitting shoes \(^{119,120}\)
and there is evidence that the constriction associated
with tightly fitting shoes predisposes to the develop-
ment of common foot problems. Menz & Morris \(^{121}\)
recently evaluated footwear fitting in 176 older people
and found that 80% wore shoes narrower than their
feet. Those who wore shoes narrower than their feet
were more likely to have corns on the toes, hallux
valgus deformity and foot pain, whereas those who
wore shoes shorter than their feet were more likely
to have lesser toe deformity. Heel elevation in women’s
shoes was associated with both hallux valgus and
plantar calluses.

Because of the strong association between ill-fitting
footwear and foot problems, footwear evaluation is an
essential first step in investigating the potential causes
of foot problems. Indeed, changing footwear may be
the only intervention necessary to successfully manage
many common foot problems, particularly those
related to toe deformities and associated hyperkerat-
totic lesions. Footwear also needs to be evaluated for
suitability in relation to the provision of toe splints,
in-shoe plantar padding and foot orthoses, as the
efficacy of these interventions is highly dependent on
the ability of the shoes to support and facilitate the
function of these devices.

The first issue to consider when assessing footwear
is whether the shoes that the older person is wearing
at the time of the consultation are those that are worn
most frequently – in many cases the shoes worn may
be ‘dress shoes’ only worn for special occasions (such
as attending medical appointments). It is also impor-
tant to ensure that indoor footwear is also assessed,
as some older people may spend more of their time
indoors than outdoors. Although indoor shoes are
generally wider fitting than outdoor shoes, \(^{121}\) they
also tend to be less supportive and are replaced far
less frequently. \(^{122}\) Key features of footwear that should
be routinely assessed in older people are summarised
in Figure 3.14.

Assessment of shoe fit should be performed while
the patient is standing, in order to accurately capture
the elongation of the foot and lateral expansion of
soft tissues of the forefoot \(^{122}\) and heel \(^{124}\) that occurs
during weightbearing. The time of day may also need
to be considered, as, although foot volume does not
appreciably change throughout the day in healthy

<table>
<thead>
<tr>
<th>Test</th>
<th>Description</th>
<th>Cut-off score that indicates increased risk of falling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unipedal stance</td>
<td>Measurement of the time (in seconds) that an individual can stand on one leg unsupported</td>
<td>&lt;30 s</td>
</tr>
<tr>
<td>Functional reach test</td>
<td>Measurement of the distance that an individual can reach forward without moving their feet</td>
<td>&lt;15 cm</td>
</tr>
<tr>
<td>Walking speed</td>
<td>Measurement of the time taken to walk a certain fixed distance (usually 6 m)</td>
<td>&lt;0.56 m/s</td>
</tr>
<tr>
<td>Timed up and go test</td>
<td>Measurement of the time taken to stand from a chair, walk 3 m, turn around and sit back down</td>
<td>&gt;14 s</td>
</tr>
</tbody>
</table>
young adults, prolonged standing and weight-bearing activity may influence the volume of the foot in older people, particularly those with venous insufficiency. Foot length (from heel to longest toe) and width (at the level of the forefoot) measurements can be taken with a ruler (or Brannock device) and the measurements converted to shoe size measures using a conversion chart (Fig. 3.15). As a general rule, the shoe should be approximately 12 mm longer than the longest toe. It may be also useful to provide patients with a visual indication of the disparity between their foot size and their shoe size. This can be very simply and effectively demonstrated by making a tracing of the patient’s bare foot on a piece of paper, and using the same piece of paper to trace around their shoe (Fig. 3.16). The depth of the shoe is of equal importance to its length and width, particularly because the depth of a shoe does not increase as shoe size increases. This aspect of shoe fit is more difficult to accurately measure; however, careful observation and palpation of the shoe will enable the identification of deformed or stretched areas of the upper caused by toe deformities.

Assessing the wear patterns of footwear may provide useful diagnostic information regarding foot structure and function. Excessive medial or lateral wear marks on the sole may indicate a pes planus or pes cavus foot type, while deformation and creasing of the toe box of the shoe may indicate hallux valgus or hallux limitus. However, wear patterns are also influenced by bodyweight, the mechanical properties of materials the shoe is manufactured from, how long the shoe has been worn for and the level of physical activity of the wearer and these observations therefore need to be interpreted with a certain degree of caution.

Finally, the inside of the shoe should always be examined for evidence of exposed seams or foreign bodies (particularly in older people with peripheral neuropathy), as even minor irregularities may contribute to the development of skin lesions. Indeed, a study of 669 people presenting with foot ulcers at a diabetes clinic in the UK indicated that the most commonly reported trigger event was friction from footwear.127
FOOTWEAR AND FALLS

An additional consideration when assessing footwear in older people is their potential contribution to impaired balance and falls. Certain footwear characteristics, such as high heels, soles with poor grip and inadequate fixation, have been associated with impaired gait, balance, falls and hip fracture (Ch. 12). A standardised screening tool – the Footwear Assessment Form – has been developed for the purpose of assessing footwear in relation to balance and falls (Fig. 3.17). Patients with a history of falls whose footwear exhibits multiple potentially hazardous features should be advised to consider the purchase of more appropriate shoes. The role of footwear in falls is discussed in more detail in Chapter 12.

ASSESSING OUTCOMES OF TREATMENT

Assessing the effectiveness of clinical treatments in older people can be difficult. In many cases the endpoint is not clearly defined, as older people generally present with multiple presenting complaints, the underlying conditions responsible for these complaints have been present for a long period of time, and complete resolution of the condition is not always possible. For example, while the effectiveness of orthotic therapy for an acute episode of heel pain in a young person may be adequately assessed using a simple visual analogue pain scale, the effectiveness of ongoing ‘maintenance’ treatments for chronic keratotic lesions associated with fixed deformities is more difficult to quantify. The value of ongoing maintenance, however, should not be underestimated, as recent studies have demonstrated that significant declines in foot health occur when older people are discharged from ‘routine’ podiatry services.

Despite the difficulties in quantifying outcomes in older people, some form of outcome assessment is useful to assist in formalising the goals of treatment. The best approach is to involve the patient as much as possible by asking them what they hope to achieve from the treatment. Patient expectations of treatment may include a reduction in (or complete resolution of) pain, reduction in the size or complete healing of a foot ulcer, prevention of skin breakdown or infection, maintenance of adequate foot hygiene or maintenance of mobility (e.g. being able to walk to shops without pain or limitation). By matching patient expectations of treatment to some form of outcome measure, the
assessment process can be made more meaningful for both the patient and clinician and progress in achieving the treatment goal can be more easily documented. In addition to the previously discussed pain scales and functional tests, other tools, such as pain diaries and wound measurement charts, may also be useful for assessing treatment outcomes.

**SUMMARY**

The general principles of lower limb assessment in older people are essentially the same as for younger people, and the clinical examination should be equally thorough and systematic. Key additional considerations when assessing older people include the variability of the ageing process, the multifactorial nature of foot disorders in older people and the broader implications of mobility impairment. The clinical assessment techniques outlined in this chapter will assist clinicians in the accurate diagnosis of lower limb disorders and contribute to the development of targeted and effective management strategies for older people.

**References**

48. Richardson J. The clinical identification of peripheral neuropathy among older persons. Archives


Keratotic disorders are one of the most prevalent foot problems in older people, affecting between 20% and 65% of people over 65 years of age. Although often considered a relatively minor complaint, keratotic lesions can cause considerable pain and disability. It has been demonstrated that older people with plantar keratotic lesions have greater difficulty walking on level ground and ascending and descending stairs, and perform worse in tests of balance ability. Furthermore, if left untreated, keratotic lesions may cause damage to deeper tissues and lead to ulceration. Therefore, the accurate diagnosis and management of keratotic disorders is an essential component of foot care for older people.

There are two main types of keratotic lesion – calluses and corns (Table 4.1). Calluses (also known as tylomas, callosities and keratomas) present as a broad-based, diffuse thickening of the stratum corneum and are most commonly located under the metatarsal heads (Fig. 4.1). Calluses vary in colour from white to grey-yellow; however, they may also occasionally appear brown or red because of extravasation of blood in the underlying dermis. Calluses under the metatarsal heads have a characteristic topography that may reflect differences in weightbearing patterns under the foot when walking. Merriman et al evaluated lesion patterns in 243 chiropody patients and found that the most common presentation was under the second to fourth metatarsal heads, followed by the second
Similar observations were reported by Springett et al.\textsuperscript{11} and Grouios,\textsuperscript{12} who found the most common presentation to be the second metatarsal head (30\% and 32\% of patients respectively), followed by the first metatarsal head (21\% and 23\% of patients respectively). The role of limb dominance in the formation of plantar keratotic lesions is unclear. While Springett et al.\textsuperscript{11} found no significant difference in prevalence according to preferred limb in 319 podiatry patients, Grouios\textsuperscript{12} found a higher prevalence of lesions on the dominant foot in 115 athletes.

Corns (also known as \textit{heloma} or \textit{clavi}) are a more discrete, circumscribed area of thickening with a central core that may penetrate into the dermis.\textsuperscript{13} Three subtypes of corn have been recognised: hard corns (\textit{heloma durum}), soft corns (\textit{heloma molle}) and seed corns (\textit{heloma milliare}). The distribution patterns of these lesions vary (Fig. 4.3). Hard corns, the most common type of corn, appear as a firm, dry mass with a polished surface and are found on the interphalangeal joints of the toes (Fig. 4.4A, B) and under the metatarsal heads. Occasionally, hard corns may develop beneath the nail plate (referred to as \textit{subungual heloma}) in response to pressure from footwear (Fig. 4.5). Hard corns can become infiltrated with blood vessels and/or nerve endings from the papillary dermis, and are then referred to as vascular corns (\textit{heloma vasculare}) or neurovascular corns (\textit{heloma neurovasculare}). If left untreated, longstanding hard corns may become surrounded by a meshwork of fibrous tissue (known as fibrous corns or \textit{heloma fascia}). Soft corns (\textit{heloma molle}) develop between the toes and have a characteristic rubbery texture due to the apposition of the toes preventing adequate evaporation (Fig. 4.6).\textsuperscript{14,15} Seed corns (\textit{heloma milliare}) are small, superficial clusters of porokeratotic cells found embedded in plantar calluses, scattered around the heel or on non-weight-bearing areas of the plantar surface (Fig. 4.7).\textsuperscript{16} Seed corns are generally not painful.

### Aetiology

**Pathogenesis**

The physiological mechanism responsible for the development of keratotic lesions is not fully under-
normal healthy skin undergoes accelerated keratinisation and a decreased rate of desquamation, resulting in an increase in the thickness of the stratum corneum.\textsuperscript{17} This process, sometimes referred to as \textit{physiological hyperkeratosis}, is considered to be a protective mechanism that prevents damage to deeper tissues by dispersing the applied forces over a larger area and volume of skin. Histological studies have revealed several notable changes in calloused skin, including an increase in the thickness of the stratum corneum and stratum granulosum, a decrease in density (but increase in thickness) of keratinocytes and an exaggerated pattern of rete pegs.\textsuperscript{18} These
changes are thought to represent an increased rate of epidermal cellular production and an associated decrease in the differentiation of keratinocytes as they progress to the upper layers of the skin. Corns have a similar structure; however, the underlying dermis exhibits significant degeneration of collagen fibres and an increased number of fibroblasts.\textsuperscript{19–21}

For reasons that are still unknown, in some individuals the process of hyperkeratosis becomes excessive, resulting in a large build-up of dense, keratinised tissue. Further pressure applied to the lesion leads to a cycle of skin injury, repair and adaptation, and the compression of nerve endings in the papillary dermis caused by the lesion leads to pain (Fig. 4.8). If left untreated, keratotic lesions can cause considerable damage to deeper layers of the skin, particularly in people with diabetes. Indeed, the presence of plantar keratotic lesions is a strong predictor of foot ulceration in people with diabetic peripheral neuropathy.\textsuperscript{9}
Four plantar pressure measurement studies have provided evidence that plantar calluses tend to develop in regions of elevated pressure. Robertson\textsuperscript{22} compared 60 people with painful calluses under the first metatarsophalangeal joint to a matched control group and found that the peak plantar pressure was significantly higher under all metatarsophalangeal joints (including a 116% increase under the first metatarsophalangeal joint) in the group with callus. A similar result was reported by Potter & Potter,\textsuperscript{23} who assessed pressures at a range of sites in people with and without calluses and reported an average increase in pressure of 25% at sites with an overlying callus. In a study of 23 people with diabetes, Pataky et al\textsuperscript{24} observed that those with calluses under the third metatarsophalangeal joints exhibited 10% higher pressures than those without. Finally, the largest study so far conducted (involving 292 people aged 62–96 years of age) reported that peak plantar pressures were between 9% and 12% higher in callused regions of the forefoot, with the exception of the first metatarsophalangeal joint and the lesser toes.\textsuperscript{25} Although the magnitude of pressure differences reported in these studies varies considerably, there does appear to be a relationship between elevated pressures and calluses, which is further supported by studies reporting a reduction in pressure after the lesions are removed with a scalpel.\textsuperscript{24,26,27}

The pathogenesis of seed corns has received little attention in the literature. Earlier reports suggested that these lesions were crystalline deposits of pure cholesterol; however, a chromatographic analysis by O’Halloran\textsuperscript{28} revealed that, while the cholesterol content of seed corns was higher than that of normal skin, it was no different to that of hard corns, indicating that the cholesterol content of skin is a marker of keratinocyte proliferation. Vitamin deficiency, genetic predisposition to dry skin and fungal infection have also been implicated.\textsuperscript{29,30}

**Risk factors**

No prospective studies have been undertaken to determine the risk factors for the development of keratotic lesions, so our knowledge is limited to case-control studies and clinical observations. Posited risk factors for keratotic lesion formation are summarised...
in Table 4.2 and can be divided into intrinsic factors (such as age, sex, co-morbidities and foot deformities) and extrinsic risk factors (such as ill-fitting footwear and occupational or lifestyle factors). Each of these factors is discussed in detail in the following section.

The community-based epidemiological studies outlined in Chapter 1 indicate that the prevalence of corns and calluses increases with age\(^5,^31,^32\) and female sex.\(^3,^32\) The increased prevalence with advancing age is most probably related to age-related changes in skin structure and function (particularly the decreased function of sweat glands and thinning of the dermis), in addition to the associated increase in the prevalence of foot deformities, while the association with female sex may be partly attributable to footwear. Several authors have speculated that plantar calluses may be associated with increased body mass index\(^12,^33,^34\) due to the subsequent increase in weightbearing pressures.\(^35,^36\) In particular, heel calluses (and associated fissuring) appear to be highly prevalent in obese older women who wear shoes without an enclosed heel counter.

Keratotic lesions are common in people with systemic diseases such as diabetes,\(^37\) rheumatoid arthritis,\(^38\) stroke\(^39\) and systemic sclerosis;\(^40\) however, whether the prevalence of calluses and corns is greater in people with these conditions compared to the general older population remains unclear. Two case-control studies have shown that the prevalence of calluses in diabetic and non-diabetic older people is similar;\(^41,^42\) however, Woodburn et al\(^43\) have shown that people with rheumatoid arthritis do have a higher prevalence of plantar forefoot calluses compared to age-matched controls. The likely mechanism for the speculated increased prevalence associated with these conditions is the associated increase in foot deformity and diminished resilience of the skin.

Corns and calluses are frequently associated with foot deformities such as hallux valgus, hallux limitus and lesser toe deformities, because of changes in plantar pressure distribution when walking and the inherent difficulty in obtaining footwear to accommodate bony prominences.\(^44,^45\) In a sample of 135 older people, Menz et al\(^8\) have shown that plantar calluses were more prevalent in those with hallux valgus, whereas corns on the toes were more prevalent in those with lesser digital deformity. The relationship between foot posture, range of motion and plantar lesions is not as clear, although Woodburn et al\(^43\) reported that people with rheumatoid arthritis and a valgus heel had a higher prevalence of plantar calluses on the medial forefoot than those with a neutral heel, and Bevans & Bowker\(^33\) have shown that a pronated foot type, limited first metatarsophalangeal joint motion and limited ankle joint range of motion are associated with the presence of calluses in people with diabetes. Finally, foot surgery is a well-recognised cause of plantar lesions (referred to as transfer lesions), which frequently develop in response to the altered weightbearing patterns following procedures that involve metatarsal shortening.\(^46,^47\)

Perhaps the most common risk factor for keratotic lesions in older people is ill-fitting footwear and the wearing of shoes with an elevated heel. It has long been recognised that many older people wear shoes that are too narrow or too short, leading to compression of the toes in the front of the shoe and subsequent development of lesions.\(^48,^49\) In addition, wearing shoes with an elevated heel has been shown to markedly increase weightbearing pressures on the forefoot, a factor that is likely to predispose to the development of plantar lesions.\(^50^-^53\) In addition, wearing shoes with an elevated heel has been shown to markedly increase weightbearing pressures on the forefoot, a factor that is likely to predispose to the development of plantar lesions.\(^50^-^53\) These associations were recently confirmed by Menz & Morris,\(^54\) who took tracings of the feet and shoes of 176 older people and found that more than three-quarters of the sample wore shoes narrower than their feet. An assessment of foot problems revealed that wearing shoes substantially narrower than the foot was associated with corns on the toes, hallux valgus deformity and foot pain, whereas wearing shoes shorter than the foot was associated with plantar calluses.
with lesser toe deformity. Wearing shoes with heel elevation greater than 25 mm was associated with hallux valgus and plantar calluses in women. A less common potential footwear-related risk factor for plantar calluses is the use of sandals with multiple raised projections designed to stimulate the soles when walking. Yoshii et al\textsuperscript{55} reported 13 cases of plantar calluses in otherwise healthy people that had developed after wearing such shoes, which they labelled ‘health sandals keratosis’. In each case, the lesions resolved after patients stopped wearing the sandals.

Occupational and lifestyle factors, such as extended periods of weightbearing and performing repetitive activities involving the foot, are also likely to play a role in the development of keratotic lesions. Several examples have been described in the literature, such as the formation of dorsolateral foot lesions in people who sit cross-legged for long periods for either work\textsuperscript{56} or prayer (the so-called ‘Mecca foot’).\textsuperscript{57,58} Conversely, extended periods of bed rest may also lead to the development of calluses on the posterior heel and malleoli, which may progress to pressure ulcers if pressure redistribution is inadequate.\textsuperscript{59}

Less common causes of keratotic lesions

The preceding discussion has focused on mechanically-induced hyperkeratosis, which is the most common cause of corns and calluses in older people. However, there are many, less commonly-encountered conditions which may manifest as keratotic lesions on the foot, such as palmoplantar keratoderma (Fig. 4.9).\textsuperscript{60,61} A brief summary of these conditions is provided in Table 4.3.

\section*{ASSESSMENT AND DIAGNOSIS}

The diagnosis of keratotic lesions is relatively straightforward, as their appearance is generally stereotypical and there are few common differential diagnoses to consider. Mechanically induced lesions can be differentiated from hyperkeratosis caused by inherited dermatological diseases or chemical toxicity by taking a thorough medical history and from clinical observations of lesion distribution patterns. Mechanically induced lesions will appear on weightbearing areas or bony prominences subjected to pressure from footwear, whereas keratotic lesions due to other causes are generally more widespread and associated with similar lesions on the palms. Calluses and corns can sometimes be confused with verrucae (warts), and indeed longstanding warts may develop a thick covering layer of hyperkeratosis. However, verrucae do not generally form on weightbearing areas, are more acutely painful when lateral pressure is applied to the lesion, and will exhibit characteristic pinpoint bleeding when debrided because of the presence of thrombosed blood vessels within the lesion itself.\textsuperscript{13,45,62,63}
<table>
<thead>
<tr>
<th>Classification</th>
<th>Condition</th>
<th>Aetiology</th>
<th>Appearance</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inherited disorders</td>
<td>Palmoplantar keratoderma</td>
<td>Autosomal dominant</td>
<td>Diffuse thick hyperkeratosis of palms and soles, often associated with fissuring</td>
<td>Emollients, keratolytics, debridement</td>
</tr>
<tr>
<td></td>
<td>Mal de Meleda</td>
<td>Autosomal recessive</td>
<td>As above, in addition to discrete keratoses on extensor surfaces</td>
<td>Emollients, keratolytics, debridement</td>
</tr>
<tr>
<td></td>
<td>Keratoderma punctata</td>
<td>Autosomal dominant</td>
<td>Multiple punctuate hyperkeratotic lesions on palms and soles</td>
<td>Emollients, keratolytics, debridement</td>
</tr>
<tr>
<td></td>
<td>Keratosis follicularis (Darier’s disease)</td>
<td>Autosomal dominant</td>
<td>Small scaly or waxy papules most commonly found on scalp, chest and back. Appear as punctuate keratoses when the palms and soles are affected</td>
<td>Emollients, keratolytics, corticosteroids</td>
</tr>
<tr>
<td></td>
<td>Palmoplantar keratoderma</td>
<td>Autosomal dominant</td>
<td>Diffuse thick hyperkeratosis of palms and soles, often associated with fissuring</td>
<td>Emollients, keratolytics, debridement</td>
</tr>
<tr>
<td>Disorders associated with malignancy</td>
<td>Diffuse palmoplantar keratosis (Howel-Evans’s syndrome)</td>
<td>Precedes oesophageal carcinoma</td>
<td>Diffuse hyperkeratosis of palms and soles</td>
<td>Emollients, keratolytics, debridement</td>
</tr>
<tr>
<td></td>
<td>Acrokeratosis paraneoplastica (Bazex’s syndrome)</td>
<td>Associated with upper respiratory and gastrointestinal carcinoma</td>
<td>Diffuse hyperkeratosis of palms and soles, nail hypertrophy</td>
<td>Emollients, keratolytics, debridement</td>
</tr>
<tr>
<td>Other</td>
<td>Ichthyosis</td>
<td>Group of disorders. May be inherited or acquired</td>
<td>Characteristic dry ‘fish-scale’ lesions with fissuring on elbows, knees, forehead, arms, thighs, palms and soles</td>
<td>Emollients, keratolytics, retinoic acid, corticosteroids</td>
</tr>
<tr>
<td></td>
<td>Actinic keratosis (‘senile keratosis’)</td>
<td>Excessive or prolonged sunlight exposure</td>
<td>Well-defined, raised red papules or plaques with rough surface of adherent scales, most commonly located on exposed areas of skin</td>
<td>Cryotherapy, curettage, electrotherapy, topical 5-flourouracil</td>
</tr>
<tr>
<td></td>
<td>Arsenical keratosis</td>
<td>Exposure to arsenical compounds in medications, insecticides or drinking water</td>
<td>Discrete, yellow, punctuate round lesions on palms and soles</td>
<td>Emollients, keratolytics, debridement</td>
</tr>
<tr>
<td></td>
<td>Keratoderma climacterium</td>
<td>Cause unknown. Occurs in postmenopausal women and is associated with obesity and hypertension</td>
<td>Marked thickening of palms and soles with deep fissures</td>
<td>Emollients, keratolytics, debridement, corticosteroids</td>
</tr>
</tbody>
</table>
Once differential diagnoses are ruled out, the next step is to determine the underlying cause of the lesion. This will involve careful observation and palpation, noting the presence of hallux valgus, hallux limitus, lesser toe deformities, relative lengths of the metatarsals and overall posture of the foot (pronated, neutral or supinated). Joint range of motion assessments are also useful, as restricted motion of metatarsophalangeal joints may result in the generation of excessive plantar pressures when walking. Footwear should be carefully examined, with particular emphasis placed on the width and depth of the toe-box, the height of the heel and the presence of irregularities in the inner lining of the shoe (such as prominent stitching) that may be pressing on the foot. In-shoe devices such as insoles, foot orthoses, ankle–foot orthoses or other forms of bracing should also be evaluated. The plantar pressure systems outlined in Chapter 3 may be useful to locate and quantify regions of high pressure under the foot but they are rarely required to confirm a diagnosis. Similarly, the use of radiographs to visualise bony prominences, or histological analysis of the lesion, is generally not necessary.

**TREATMENT**

## CONSERVATIVE TREATMENTS

**Lesion debridement**

The first step in the treatment of keratotic lesions is sharp debridement or enucleation with a scalpel (Figs 4.10, 4.11). This procedure requires a considerable level of manual dexterity, particularly in the case of deep-seated neurovascular corns or interdigital soft corns. Debridement and enucleation provide immediate symptomatic relief, increase the bearable pressure threshold of the foot and reduce weightbearing pressures by up to 30%. There is also some preliminary evidence that debridement of lesions may improve mobility in older people. Balanowski & Flynn assessed functional ability (including ascending and descending stairs, an alternate stepping test and walking speed) and balance in people aged over 65 before and after scalpel debridement of painful plantar keratoses. After debridement, there was a significant reduction in pain and significant improvements in all three functional tests, which were maintained at a follow-up appointment 1 week later.

Debridement and enucleation of keratotic lesions, however, provides only short-term relief of symptoms and, unless the underlying cause is addressed, most lesions will recur after a number of days or weeks. The optimum frequency of repeat appointments for ongoing management of keratotic lesions is unknown, as the rate of recurrence of keratotic lesions is highly variable. Potter & Potter have recently shown that callus regrowth over the first 2 weeks following debridement varies considerably, even within individuals. Three distinct patterns were observed: slow-growing calluses, which only grew to 30% of their original size during the 2-week period; medium-growing calluses, which grew to 30–60% of their original size; and fast-growing calluses, which grew to
60–70% of their original size. The surface area and thickness of the original lesion did not appear to influence the rate of regrowth; however, it was reported that lesions over the fifth metatarsal head were more likely to be fast-growing and that lesions under the second metatarsal head were more likely to be slow-growing. The underlying physiological mechanisms for these differences remain unclear but are likely to be related to level of activity, footwear characteristics and level of skin hydration.

Topical treatments

A wide range of topical treatments have been proposed to both chemically debride keratotic lesions and inhibit their regrowth. In 1782, Laforest prescribed a concoction consisting of pork fat and ‘the mousse that forms around boats’ and, since that time, a similarly colourful array of ointments, tinctures and poultices have been recommended for keratotic lesions. Contemporary topical agents include salicylic acid, silver nitrate, silicone and hydrocolloid wound dressings. Although anecdotal reports and several short-term, uncontrolled studies suggest that these techniques may be effective, very few controlled trials have been undertaken.

Salicylic acid, first described as a treatment for keratotic lesions in ancient Greece, is believed to lower the pH of the stratum corneum, thereby leading to swelling, maceration and eventual desquamation of the lesion. Lang et al. have shown that ‘corn plasters’ containing 40% w/w salicylic acid are more effective than non-medicated placebo pads, producing complete enucleation of 62% of digital hard corns over a 21-day period. Subsequent comparison studies of different types of corn plaster (i.e. different strengths and delivery systems) have reported similar rates of lesion resolution; however, the adverse effect of excessive maceration of surrounding tissue appears to be more likely in stronger preparations incorporating a waxy matrix rather than an adhesive matrix. The use of salicylic acid also needs to be very carefully considered in people with diabetes, as several cases of foot ulceration and infection have been reported following its use.

Hydrocolloid dressings, most commonly used in the management of open wounds, have recently been evaluated as a potential treatment for keratotic lesions because of their effect on skin hydration. An uncontrolled study of 43 people with corns and calluses reported that 21% of corns and 14% of calluses had resolved after 5 weeks of hydrocolloid treatment. A subsequent randomised trial comparing three adhesive dressings (compressed felt, polymer gel and a hydrocolloid) for the treatment of symptomatic corns found that, while all treatments were effective in reducing pain and the size of the lesion, the hydrocolloid was reported by patients to be easier to use, easier to keep in place and more aesthetically pleasing. However, whether this benefit is significant enough to justify the extra cost of the dressing is arguable.

Heel calluses, which often present with associated skin dryness and fissuring (Fig. 4.12), can be difficult to treat, particularly in older people who are overweight and wear shoes without an enclosed heel counter. Following debridement of the overlying callus and the edges of the fissures, topical application of salicylic acid or emollient creams may be effective, in addition to the firm application of an adhesive bandage to limit lateral expansion of the heel pad when weightbearing. The application of cyanoacrylate adhesives to seal deep heel fissures has also been reported to be effective, producing wound closure strength equivalent to suturing.

Injection therapy

In addition to topical applications, a range of preparations for intralesional or sublesional injection have
been reported, including sodium chloride, alcohol and liquid silicone. Dockery & Nilson have reported clinical success in resolving chronic plantar keratotic lesions using weekly 0.5–1.0 ml intralesional injection of a 4% sclerosing solution consisting of 2 ml absolute ethyl alcohol with 48 ml of 2% lidocaine with adrenaline (epinephrine) 1 : 100 000. No controlled trials have been undertaken to adequately assess the efficacy of this approach, and the mechanism of action is also unclear. It has been suggested that the injection acts as an ‘internal pad’, thus spreading weightbearing forces over a larger area; however, the duration of this effect is unknown.

Similar anecdotal reports regarding the efficacy of liquid silicone injections have been reported by Balkin; however, only two controlled trials have so far been undertaken. Tollafiel et al compared the efficacy of liquid silicone and saline injections in 31 people with plantar lesions and found no difference between the groups with regard to pain, frequency of follow-up treatments or appearance of the lesions. More recently, a randomised, placebo-controlled trial conducted in people with diabetic peripheral neuropathy found that six injections of 0.2 ml liquid silicone were more effective in increasing plantar soft tissue thickness and reducing plantar pressure than a placebo (saline); however, there was no difference in the appearance of the calluses. A follow-up paper by these authors reported that, after 2 years, the increase in soft tissue thickness was largely maintained, although the treatment had lost some of its pressure-reducing properties. Although no serious complications were reported in these studies, skin discoloration and migration of the silicone from the injection site have been reported in a small number of cases.

**Orthotic therapy**

Redistribution or reduction of excessive foot pressures has the potential to provide longer-term relief of symptoms associated with keratotic lesions and, in some cases, complete resolution of the lesion may be possible. Simple cushioning insoles placed inside the shoe may assist in reducing the overall pressure under the foot; however, individually customised pressure redistribution insoles are likely to be more effective. Figure 4.13 shows some of the more commonly used padding designs for offloading plantar keratotic lesions. Several plantar pressure studies have confirmed that this approach is effective in redistributing pressures beneath the metatarsal heads. Similarly, the application of small pads beneath the proximal interphalangeal joints has been shown to significantly reduce pressure borne by the apices of the toes. In addition to these simple insole designs, orthoses moulded to the foot from more rigid materials such as polypropylene have also been shown to redistribute pressures to the arch of the foot, thereby reducing forefoot pressures.

Despite the significant pressure reduction achieved with insoles and foot orthoses, only three studies have demonstrated that this approach is effective in the management of calluses. Colagiuri et al randomly allocated 20 people with diabetes to receive either conventional debridement of their plantar lesions or

![Figure 4.13](https://example.com/figure413.jpg)  
**Figure 4.13** Orthotic designs used to redistribute pressure away from keratotic lesions. **A.** Plantar metatarsal pad. **B.** Plantar cover. **C.** ‘U-ed’ plantar cover. **D.** Winged plantar cover. **E.** Arch pad. **F.** Toe prop.
custom orthoses manufactured from a rigid plastic material. After 12 months, the orthotic group exhibited greater reductions in callus severity, with 16 out of 22 calluses in the orthotic group demonstrating significant improvement. More recently, Caselli et al.\textsuperscript{107} compared debridement alone to debridement in conjunction with either urethane or silicon gel insoles. After 4 weeks, a significant improvement in symptoms was observed in both insole groups, indicating that the use of insole therapy is more effective than debridement alone. Finally, Timson & Spooner\textsuperscript{70} randomly allocated 25 people with painful calluses to receive either debridement or insoles manufactured from 4 mm medium-density ethyl vinyl acetate with apertures placed at the site of the lesion. Both groups demonstrated significant reductions in pain immediately following treatment; however, the reduction was greater in the debridement group. At 6-week follow-up, pain relief was maintained in the insole group; however, pain levels in the debridement group had returned to their pretreatment level.

Alleviating pressures from keratotic lesions on the dorsum of the toes or between the toes is somewhat more difficult, as it is more dependent on the adequacy of the footwear. Several approaches have been used with anecdotal evidence of clinical success, including simple lamb’s wool, foam toe spacers and silicone gel sleeves, many of which are now available as over-the-counter products from pharmacies and supermarkets.\textsuperscript{108} Devices customised to the shape of the individual’s foot can also be manufactured from silicone elastomer materials (Ch. 11).

**Footwear modification**

If it is evident from clinical observations that the underlying cause of the keratotic lesion is related to ill-fitting footwear, it is necessary to advise the older person to consider purchasing a new pair of shoes with more adequate room in the toe-box. In some situations, however, this may not be possible for financial reasons or because of reluctance on the part of the older person to wear wider-fitting shoes. In these circumstances, it is worth considering modifying the existing footwear to accommodate the lesion. This can be achieved using shoe-stretching devices, cutting out sections of the upper, or balloon patching. Medical-grade footwear manufacturers or pedorthists will often need to be consulted to undertake these modifications, as they require considerable manual skill and the appropriate tools and materials. Before commencing this intervention, it also needs to be considered that the end result may not always be aesthetically pleasing and that the resilience and longevity of the shoe may be diminished in the process. Footwear modifications are discussed in more detail in Chapter 12.

**SURGICAL TREATMENT**

Surgical intervention for keratotic lesions is generally considered for older people with painful, chronic lesions that have failed to respond to conservative treatment, or as an option for older people who find ongoing maintenance visits inconvenient. Two broad categories are recognised – electrosurgery, a relatively atraumatic procedure that involves removing the lesion using high-frequency current, and orthopaedic surgery, which is far more invasive, has a greater potential for complications and requires lengthier periods of rehabilitation. Both approaches should be carefully considered in the context of their potential costs and benefits.

**Electrosurgery**

Electrosurgery has been used for several decades in a range of dermatological applications, most commonly in the treatment of small skin lesions such as verrucae, skin tags and naevi. The procedure employs high-frequency alternating current, which produces heat within cells, leading to modifications to the protein content, evaporation of cellular fluids and the eventual destruction of the lesion and its separation from surrounding normal skin at the level of the dermal–epidermal junction.\textsuperscript{109,110} Two different approaches are used depending on the depth of the lesion: *fulguration*, in which the electrode is held away from the skin to produce sparking at the skin surface, or *electrodesiccation*, in which the electrode is placed in contact with the skin to penetrate more deeply. Local anaesthesia is generally required prior to administration and, following treatment, sterile wound dressings in conjunction with redistributive padding should be applied.

No controlled trials have evaluated the efficacy of electrosurgery in the treatment of keratotic lesions; however, a number of case series studies report favourable results for longstanding lesions. A case series of 50 patients with vascular and neurovascular corns reported by Smith & Morrison\textsuperscript{110} indicated that 45%
of lesions completely resolved after a period of 4–6 weeks and a further 50% showed sufficient improvement to enable ongoing management with scalpel debridement. A follow-up study 4 years later reported improved rates of lesion resolution (71–90%), which the authors attributed to improvements in postoperative management. More recently, Whinfield & Forster reported a 73% reduction in pain associated with chronic hard corns 6 weeks after electrodesiccation and, at 12 months, pain levels were 58% of their pretreatment values. Although further studies are required to substantiate these findings, it would appear that electrosurgery may be useful for the treatment of chronic painful lesions in older people who have not responded to conservative treatments or who are considered not suitable for orthopaedic surgery.

Orthopaedic surgery

Surgical treatment for plantar lesions was first described by Meisenbach in 1916. Since then, there have been a plethora of surgical approaches and modifications described in the literature, involving the removal of entire metatarsals, partial or partial excision of metatarsal heads and a variety of approaches for shortening or dorsiflexing metatarsals. It is difficult to evaluate the relative success of these approaches, as few direct comparisons have been undertaken and in many studies the duration of follow-up is insufficient to adequately assess the rate of complications. Nevertheless, it is clear that lesion recurrence is relatively common, as are complications such as the development of new lesions at previously lesion-free sites (transfer lesions), reduced toe function and delayed or non-union of the osteotomy site. These complications appear to be more likely to occur when the surgical procedure involves multiple osteotomies.

Currently, the most commonly performed procedure for the surgical management of plantar lesions is the Weil osteotomy, attributed to the American podiatrist Lowell Scott Weil by Barouk. The aim of the procedure is to shorten the metatarsal, and it involves a 30° oblique osteotomy through the metatarsal head and proximal displacement of the distal fragment, followed by screw fixation and excision of the remaining dorsal overhang (Fig. 4.14). The plantar lesion is also excised to the level of the dermis. Patient satisfaction with this procedure has been reported to range between 47% and 88% of cases, with complete resolution of the lesion reported in 39–78% of cases. The most commonly reported complication associated with the procedure is floating toes (15–36% of cases), although transfer lesions are also relatively common (5–20% of cases). Although few direct comparisons of success rates according to age have been undertaken, Winson et al. have observed that complications are more likely in people aged over 65 years.

A number of authors have suggested that the Weil osteotomy is most appropriate when the affected metatarsal is excessively long, and that complications arise when the procedure is administered to normal length metatarsals. In cases where the objective of the surgery is to elevate the metatarsal without shortening it, the Schwartz osteotomy has been recommended. This procedure involves removing a wedge-shaped piece of bone from the anterior aspect of the metatarsal head, leaving a plantar hinge of bone that is then dorsiflexed and fixed by a screw (Fig. 4.15). A recent retrospective review of 25 cases.
patients reported that, while only 41% demonstrated complete resolution of their plantar lesion, there was a high level of patient satisfaction and a reduction in the number of required podiatry visits postoperatively.124

Surgical procedures for keratotic lesions on the toes are selected according to the specific associated deformity (hammer toe, claw toe, mallet toe, etc.) and the range of motion available at the metatarsophalangeal and interphalangeal joints.44,126 These procedures are described in Chapter 8.

**SUMMARY**

Keratotic lesions are among the most common foot complaints in older people, the management of which accounts for the vast majority of a podiatrist’s workload. Although often considered a minor complaint, longstanding lesions can be debilitating and severely impact on an older person’s quality of life. In most cases, keratotic lesions can be successfully managed with conservative interventions such as debridement, orthoses and footwear modifications. Surgery may be indicated for cases that fail to respond to conservative approaches; however, the risk of complications needs to be carefully considered.

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**References**


43. Woodburn J, Helliwell PS. Relation between heel position and the distribution of forefoot plantar pressures and skin callosities in rheumatoid arthritis.
78. Springett K, Deane M, Dancaster P. Treatment of corns, calluses and heel fissures with a hydrocolloid


Disorders of the skin are very common in older people.\textsuperscript{1} Surveys of clinical populations indicate that the most common presenting complaints in people aged over 65 years are eczema/dermatitis, fungal infections, pruritus, actinic keratosis, benign tumours and malignant tumours.\textsuperscript{2–7} Establishing the prevalence of skin lesions of the foot, however, is difficult, as few large-scale dermatology studies specify the body part affected by the condition and foot-specific studies tend to focus on keratotic lesions or orthopaedic conditions. The most commonly reported skin condition in older people in the large-scale, foot-specific studies is ‘dry skin’ (prevalence estimates ranging from 13\% to 27\%),\textsuperscript{8–10} followed by various classifications of foot infections (2–47\%).\textsuperscript{10–13} The most detailed data can be derived from the Achilles Foot Screening Project, which involved clinical and mycological examination of the feet of people attending dermatologists or primary care physicians in 16 countries.\textsuperscript{14} Although no doubt an overestimate because of response bias, the findings of this study indicate that between 60\% and 90\% of people aged over 65 years had evidence of foot disease, the most common condition being tinea pedis (29\% of older people).

The following chapter provides an overview of the most common skin conditions affecting the older foot, along with less common conditions with potentially serious ramifications (i.e. premalignant and malignant lesions). The reader should note, however, that the coverage in this chapter is by no means exhaustive, and it is therefore advisable to supplement this information with a general dermatology text or Dockery’s \textit{Cutaneous Disorders of the Lower Extremity}.\textsuperscript{15} It is also worth noting that while the treatment
of some of the more common skin conditions is well supported by evidence from randomised controlled trials, the management of more obscure lesions is largely informed by clinical experience. The findings of relevant systematic reviews conducted by the Cochrane Collaboration are provided where available; however, at the time of writing several of these (such as the treatment of psoriasis, cellulitis, actinic keratoses, surgical treatment for malignant melanoma and non-melanoma skin cancers) were still under development.

ECZEMA AND DERMATITIS

The term ‘eczema’ refers to any form of non-infective inflammation of the skin and is often used interchangeably with the term ‘dermatitis’. Eczema can be broadly classified as exogenous (i.e. caused by external irritants) or endogenous (i.e. caused by internal physiological factors). However, because the aetiology of many forms of eczema is unknown, such a distinction is not always possible, and indeed in some conditions a combination of external irritants and internal factors is likely to be responsible. For the same reason, determining the prevalence of eczema in older people is very difficult, with reported prevalence rates ranging between 35% and 59%. Excessively dry and scaly skin, one of the most common complaints associated with eczema affecting the foot, is reported by between 13% and 27% of those aged over 65 years. The most common forms of eczema in older people are discussed below.

XEROTIC ECZEMA

Also known as atopic dermatitis, eczema craquelé and chronic winter itch, this condition is characterised by erythematous dry scaling and fissuring of the skin, and is most commonly found on the anterolateral aspects of the legs in older people (Fig. 5.1). The lesions are often highly pruritic and continued scratching exacerbates the condition. Xerotic eczema is thought to be caused by a reduction in epidermal lipids due to excessive use of soaps and detergents, frequent bathing in very hot water, excessive room heating and inadequate household humidity. The condition is particularly common in older people residing in aged care facilities. Treatment involves the application of emollient or corticosteroid creams and educating the older person or their carer about the use of moisturising soaps. It has also been suggested that older people with severe forms of the condition should consider purchasing a humidifier.

VENOUS STASIS ECZEMA

Venous stasis eczema (also referred to as stasis dermatitis, varicose eczema or gravitational eczema) is characterised by oedema, hyperaemia, pruritus, haemosiderosis and superficial scaling of skin in the lower tibial area, and is associated with chronic venous insufficiency (Fig. 5.2). The peak incidence of onset is in the third to fourth decade, and women are three times more likely to develop the condition than men. The condition most commonly develops after a venous ulcer has healed, leaving the epidermis...
atrophic and the underlying dermis sclerotic and indurated. Treatment involves management of the underlying venous condition (e.g. limb elevation, the use of compression stockings and exercise) in addition to managing pruritus with topical corticosteroids and maintaining skin integrity with the application of emollient creams.

### DRUG-INDUCED ECZEMA

A wide range of medications may produce skin eruptions in older people and lead to the development of eczema. However, because many older people take multiple medications, it is often difficult to determine the causative agent. Furthermore, while some medications produce immediate skin reactions, others may take months or even years to manifest. Broadly speaking, six main types of drug reaction are observed: urticarial reactions, which manifest as a pruritic red wheals and are caused by an acute hypersensitivity response, morbilliform eruptions, which create erythematous macular and papular rashes, erythema multiforme, an acute bullous reaction associated with systemic symptoms such as fever and muscular pains, acroexfoliative dermatitis, which produces lichenification and superficial shedding of skin, exfoliative erythroderma, a serious condition characterised by severe pruritic scaling and desquamation, and lichenoid dermatitis, characterised by multiple flat-topped papules. Because they are potentially life-threatening, it is essential that a thorough evaluation be undertaken when older people present with suspected drug eruptions. Signs that may indicate severe reactions include pronounced erythema, skin pain, necrosis, Nikolsky’s sign (separation of the epidermis from the dermis with mild lateral pressure), swelling of the tongue, high fever, enlarged lymph nodes, shortness of breath and arthritic symptoms. Common medications associated with each of these presentations are shown in Table 5.1. Treatment of these conditions requires the identification and, if possible, discontinuation of the offending medication, along with topical therapy to maintain skin integrity.

<p>| Table 5.1: Common medications associated with different presentations of drug eruptions |</p>
<table>
<thead>
<tr>
<th>Drug eruption</th>
<th>Common causative medications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urticarial reaction</td>
<td>Aspirin, Penicillin</td>
</tr>
<tr>
<td>Morbilliform eruption</td>
<td>Ampicillin, Gentamicin, Phenothiazines, Sulphonamides, Thiazides, Quinidine</td>
</tr>
<tr>
<td>Erythema nodosum</td>
<td>Sulphonamides, Penicillin, Halogens</td>
</tr>
<tr>
<td>Acroexfoliative dermatitis</td>
<td>Aspirin, Codeine, Iodine, Sulphonamides, Phenytoin</td>
</tr>
<tr>
<td>Exfoliative erythroderma</td>
<td>Allopurinol, Cimetidine, Phenytoin, Iodine, Penicillin, Sulphonamides</td>
</tr>
<tr>
<td>Lichenoid dermatitis</td>
<td>Beta-blockers, Non-steroidal anti-inflammatory drugs, Thiazides, Quinidine</td>
</tr>
</tbody>
</table>

### PAPULOSQUAMOUS DISEASES

#### PSORIASIS

Psoriasis is a chronic inflammatory skin condition characterised by the formation of well demarcated erythematous plaques and superficial scales involving any part of the body but most commonly the scalp, elbows and knees (Fig. 5.3). Foot and toenail involvement is common, and up to 30% of people with psoriasis will also develop arthropathy in the distal joints, including the interphalangeal joints of the toes. Psoriasis affects approximately 2% of the population and can begin at any age; however, the peak incidence occurs in the second and third decades. The cause of psoriasis is not well understood; however, a positive family history is evident in 35% of patients and the condition appears to be triggered by a range of factors such as trauma, infection, some medications, alcohol, smoking and stress.

Three main types of psoriasis have been recognised: chronic plaque psoriasis (also referred to as ordi-
nary psoriasis or psoriasis vulgaris), which is the most common form, guttate psoriasis, in which several drop-like lesions form symmetrically on the trunk following a streptococcal throat infection, and pustular psoriasis, which is more common in older women and is characterised by the development of erythematous, yellow to brown vesicles on the palms and arch of the foot (Fig. 5.4).\textsuperscript{15,34} Two key clinical features of chronic plaque psoriasis can greatly assist in establishing a diagnosis: Auspitz’s sign, the appearance of pinpoint bleeding when the superficial scales are removed, and the Koebner phenomenon, the appearance of psoriatic lesions at sites of previous injury to the skin. Toenail involvement is characterised by pitting of the nail plate, formation of subungual hyperkeratosis and, in severe cases, onycholysis (separation of the nail plate from the underlying nail bed).\textsuperscript{15,34}

First-line treatment of psoriasis involves the management of lesions with topical emollients, corticosteroids, tar-based preparations or salicylic acid.\textsuperscript{35} However, a recent systematic review indicated that these treatments provide only temporary relief and recurrence is common, often in a more severe form than the original presentation (the so-called ‘rebound effect’).\textsuperscript{36} For long-standing psoriasis, systemic treatments include photochemotherapy (exposure of the skin to ultraviolet A following oral administration of psoralen), oral retinoid (a vitamin A derivative, often used in conjunction with ultraviolet A) and methotrexate (a folate antagonist with anti-inflammatory and immune-modulating effects).\textsuperscript{36}

\section*{Lichen Planus}

Lichen planus is an inflammatory condition characterised by the formation of sharply defined, flat, shiny, polygonal, pruritic papules on the wrists, lumbar region, scalp, tibial area and, less commonly, the foot (Fig. 5.5). The peak incidence of onset is between the ages of 30 and 60 years, and women are affected more frequently than men.\textsuperscript{28} The aetiology is not fully understood. The most common site of foot involvement is the plantar medial arch,\textsuperscript{37,38} where the lesions may develop a more hyperkeratotic appearance than other regions and, in rare cases, may ulcerate.\textsuperscript{39} Nail
involvement may also occur, resulting in thinning of the nail plate, formation of subungual hyperkeratosis and fusion of the proximal nail fold to the nail bed. Spontaneous resolution occurs in most cases over a period of 6–18 months; however, relapses occur in 10–25% of cases. Treatment involves topical or oral corticosteroids, and antihistamines to manage pruritus. In severe cases, photochemotherapy may be considered.

SKIN INFECTIONS

As stated in Chapter 2, ageing is associated with significant changes to the structure and function of the skin. Several of these changes, such as the reduction in the number of Langerhans cells and the reduction in the number of capillary loops in the dermis, affect the barrier function of the skin and reduce the efficacy of the immune response. As a consequence, the risk of skin infection increases significantly with advancing age. In the foot, this risk is further exacerbated by the wearing of footwear and hosiery, which provides an ideal warm and humid environment for growth of many types of bacteria and fungi. In the presence of minor breaks in the skin, such as fissuring between the toes, superficial infections can quickly develop into far more serious conditions that may be limb-threatening or even life-threatening. The following section provides an overview of the most common skin infections seen in older people. Nail infections are covered in Chapter 6.

ERYSIPELAS AND CELLULITIS

The term erysipelas refers to an acute infection of the dermis, whereas cellulitis refers to an acute or chronic infection of connective tissue. However, because erysipelas can extend to deeper tissues and cellulitis can extend superficially, the distinction between the two conditions is somewhat vague. For the sake of simplicity, the term cellulitis is now commonly used to encompass both conditions. Cellulitis is common in older people, with incidence rates ranging from 4 to 25 cases per 10 000 person-years in those aged over 65 years. The most common bacterium responsible for cellulitis is Streptococcus pyogenes, followed by Staphylococcus aureus. Anaerobic organisms such as Peptostreptococcus, Clostridium and Porphyromonas are occasionally isolated from affected skin.

The bacteria gain access to the deeper tissues through open wounds, such as leg or foot ulcers, interdigital fissures and subungual lesions, or as the result of surgery. Several case-control studies have confirmed that the presence of chronic fungal infection affecting the interdigital spaces markedly increases the risk of cellulitis. Furthermore, foot surgery has been shown to be associated with higher postoperative infection rates than procedures performed on other parts of the body. Death from cellulitis-related septicaemia has also been reported in an 87-year-old woman with peripheral vascular disease following non-surgical treatment for an ingrown toenail.

The key presenting features of cellulitis are swelling, erythema and pain in the affected limb, accompanied by high fever and lymph node enlargement. A clearly demarcated margin indicating the spread of the bacteria is often visible (Fig. 5.6) and in severe cases there may be evidence of necrosis or gangrene. Admission to hospital is generally necessary, as untreated cellulitis may lead to septicaemia. Treatment involves antibiotics, the selection of which is dependent on determining the causative bacteria. In cases related to leg ulcers, broad-spectrum antibiotics are generally used as it is likely that multiple species of bacteria are involved.

PITTED KERATOLYSIS

Pitted keratolysis is a condition caused by infection of the plantar stratum corneum by the Corynebacterium species of bacteria and, less commonly, Micrococcus sedentarius or Dermatophilus congolensis. The condition frequently develops in barefoot populations, or in people whose occupation subjects them to prolonged exposure of the feet to wet conditions. However, pitted keratolysis may also develop in people with pre-existing hyperhidrosis. The presence of the bacteria leads to the formation of hyperhidrotic crateriform pits on the plantar surface of the heel and forefoot, which may coalesce to form irregularly shaped erosions (Fig. 5.7). The skin develops a characteristic ‘sliminess’ and is accompanied by a pungent odour. Most cases are asymptomatic. Treatment involves the application of astringent foot soaks or powders, and topical antibiotics.

TINEA PEDIS

Fungal infection of the foot (tinea pedis) is extremely common in older people. Epidemiological studies...
indicate that between 5% and 20% of community-dwelling people aged over 65 years have some form of fungal infection.10,59 The Achilles Foot Screening Project, which involved clinical examination of the feet of people attending dermatologists or primary care physicians in 16 countries,14 indicated that the second most commonly diagnosed condition in older people was fungal infection of the skin, which was observed in 29% of the sample.60 A follow-up study involving 90,085 older patients across all the participating European countries61 reported that almost half had clinical evidence of fungal foot infection.

Fungal skin infections are caused by a group of fungi known as dermatophytes, so named because of their ability to penetrate the stratum corneum. For foot infections, the most common infective organisms are *Trichophyton rubrum*, *Trichophyton mentagrophytes* (also known as *Trichophyton interdigitale*) and *Epidermophyton floccosum*.60 The presence of these organisms in the skin causes keratin destruction and an inflammatory response, leading to the characteristic signs of erythema and desquamation and the common presenting complaint of severe pruritus. There are three major types of fungal skin infection: interdigital tinea pedis, which develops between the toes and has a moist, macerated, scaly appearance, moccasin foot, characterised by a hyperkeratotic, dry scaling of the lateral and plantar surfaces of the foot, and vesicular (or bullous) tinea pedis, in which vesicles or bullae filled with clear fluid develop on the plantar surface or interdigital spaces. A fourth category, ulcerative tinea pedis, may develop when longstanding interdigital tinea pedis extends on to the dorsal or plantar surfaces of the foot. In older people, the most common form is interdigital tinea pedis, which is often triggered by inadequate drying between the toes and occlusion of the interdigital spaces by toe deformity and/or ill-fitting footwear. Interdigital tinea pedis is also commonly associated with concurrent fungal nail infection (*onychomycosis*) in older people (Fig. 5.8), and, as stated previously, is a significant risk factor for bacterial cellulitis.47–49

First-line treatment of tinea pedis involves the application of topical antifungal medications. Several...
such medications have been developed, including allylamines, azoles, undecenoic acid and tolnaftate. The recent Cochrane review of 72 randomised controlled trials concluded that allylamines, azoles and undecenoic acid were all effective compared to a placebo, with allylamines curing slightly more infections than the azoles. However, because allylamines are more expensive, the authors recommended that the most cost-effective approach is to first treat with azoles or undecenoic acid, and to use allylamines only if that fails. Cure rates of 65–91% have been reported; however, it is likely that the cure rate is somewhat lower in older people.

Oral medications for fungal infections of the skin first became available in 1958 in the form of griseofulvin. Although widely used, griseofulvin was not effective against non-dermatophyte fungi and was associated with gastrointestinal side-effects. More recent oral medications, such as the azoles (ketoconazole, itraconazole and fluconazole) and allylamine (terbinafine) are considerably more effective. The most recent Cochrane review of 12 randomised controlled trials concluded that terbinafine is more effective than griseofulvin, and that terbinafine and itraconazole are more effective than a placebo. Mycological cure rates with terbinafine (250 mg/d for 4–6 weeks) range from 65% to 100%.

An additional consideration when managing fungal infections in older people is that the likelihood of recurrence is high, particularly if no change is made to the older person’s footwear and hosiery. It is therefore generally recommended that infected footwear and hosiery be discarded as part of the management plan, and that particular emphasis is placed on maintaining adequate foot hygiene such as drying between the toes and regularly changing socks or stockings.

**TUMOURS, CYSTS AND LESIONS**

The foot is a relatively common site for a wide range of skin lesions in older people, although the actual incidence of such lesions is extremely difficult to determine because of under-reporting and misdiagnosis. Audits of pathology laboratories, however, provide a reasonable estimate of the relative, if not absolute, frequency of different lesions. For lesions affecting the foot, a recent publication by Berlin is particularly informative. This paper reports the eventual pathology diagnosis of 307 601 specimens submitted to a podiatry-specific pathology laboratory in the USA, and indicates that verrucae are by far the most commonly biopsied skin lesion affecting the foot, followed by inclusion cysts and ganglionic cysts (see Table 5.2). Unfortunately, no age breakdown was undertaken, so the relative incidence of skin lesions in older people cannot be determined.

While many of these conditions are asymptomatic when located elsewhere on the body, foot lesions are frequently problematic due to the foot’s weightbearing role and the potential for friction from footwear and hosiery. The following section provides a brief overview of some of the more commonly encountered
lesions affecting the older foot, divided into benign lesions and premalignant or malignant lesions.

## BENIGN LESIONS

### Verrucae

Plantar verrucae (warts) are very common benign epidermal neoplasms caused by various strains of the human papilloma virus. Verrucae can develop at any age but are more common in children and adolescents. The appearance of verrucae can be highly variable, from smooth, flesh-coloured papules through to raised nodules with a cauliflower-like surface. The most characteristic features of verrucae are the disruption of normal skin lines and the presence of thrombosed capillaries within the lesion. These features can assist in differentiating verrucae from corns or calluses. In immunocompromised patients, multiple verrucae may form into clusters (known as mosaic verrucae), which often develop overlying hyperkeratosis (Fig. 5.9). Verrucae are generally self-limiting and will spontaneously regress over a period of months or years. However, verrucae on the foot can be quite painful and often require treatment.

A plethora of verrucae treatments have been reported in the literature, from various topical agents (glutaraldehyde, formaldehyde, podophyllin, podophyllotoxin, silver nitrate, salicylic acid, monochloroacetic acid and phenol) and intralesional injections (bleomycin, 5-fluorouracil) through to cryotherapy, CO₂ laser and electrocautery with curettage. The most recent Cochrane systematic review of 60 trials concluded that topical application of 15–20% salicylic acid is the most effective treatment for verrucae, with a cure rate of 75%. Somewhat surprisingly, only two placebo-controlled trials of cryotherapy have been undertaken, with both reporting no difference in cure rates between the groups.

### Acrochordons

Acrochordons, also referred to as skin tags or cutaneous tags, appear as soft, skin-coloured polyps with a smooth to pedunculated surface (Fig. 5.10). On non-weightbearing areas (most commonly the neck, chest and axillae), the lesion extends from the skin surface on a small stalk; however, if located on the plantar surface of the foot, compression results in a flatter lesion that may be covered with hyperkeratosis. Treatment is rarely necessary but if the lesion is painful it can easily be removed with a scalpel followed by electrocautery of the base of the lesion.

### Cutaneous horns

Cutaneous horns, also known as onychoma, are keratotic lesions that project outwards from the skin in the shape of an animal horn and are commonly found on the ears, hands and feet in older people (Fig. 5.11). Cutaneous horns can develop from a wide range of pre-existing dermatological lesions, including verrucae and stucco keratoses. Because of their size, cutaneous horns are frequently painful, and in older people there is a risk of malignancy at the base of the lesion. Treatment involves debridement of the lesion followed by curettage or cryotherapy.

### Dermatofibromas

Dermatofibromas are firm, raised, pigmented lesions ranging in size from a few millimetres to 1 cm in diameter, and most commonly occur in middle aged and older people. The lesions can develop anywhere on the body; however, the lower limbs are affected more frequently than the upper limbs or trunk (Fig. 5.12). Treatment is generally not necessary as the lesions are rarely symptomatic, and malignant changes are extremely rare.

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**Table 5.2 Incidence of skin lesions biopsied from the foot by podiatrists in the continental USA, Hawaii and Puerto Rico (n = 307 601)**

<table>
<thead>
<tr>
<th>Lesion</th>
<th>Number (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verrucae</td>
<td>176 053 (57.2)</td>
</tr>
<tr>
<td>Inclusion cysts</td>
<td>7 558 (2.4)</td>
</tr>
<tr>
<td>Ganglion cysts</td>
<td>7 395 (2.4)</td>
</tr>
<tr>
<td>Fibromas</td>
<td>1 779 (0.6)</td>
</tr>
<tr>
<td>Dermatofibromas</td>
<td>1 701 (0.6)</td>
</tr>
<tr>
<td>Mucous (myxoid) cysts</td>
<td>1 227 (0.4)</td>
</tr>
<tr>
<td>Hemangiomas</td>
<td>594 (0.2)</td>
</tr>
<tr>
<td>Squamous cell carcinomas</td>
<td>312 (0.1)</td>
</tr>
</tbody>
</table>

---

**Figure 5.9** A. Large verruca pedis under the first metatarsophalangeal joint following debridement of overlying callus. B. Close-up view showing thrombosed capillaries. C. Subungual verruca. D. Mosaic verrucae. (Courtesy of Lesley Newcombe, La Trobe University.)
Epidermal inclusion cysts

These cysts most commonly affect people over the age of 60 years and develop as a result of a portion of epidermis becoming implanted, either surgically or traumatically, into the underlying dermis (Fig. 5.13).

Coulter & Bouche have also described three cases of epidermal inclusion cysts developing from ill-fitting footwear. The lesions have a dome-like appearance with a thin cover of epidermis and may develop a layer of hyperkeratosis. Occasionally the lesion may drain, extruding a thick, foul-smelling keratin material. Treatment is generally not required but, if considered necessary, involves surgical excision.

Ganglion cysts

Ganglion cysts, or ganglia, are generally asymptomatic, fluctuant lesions that most commonly develop in the wrists but may also affect the lower limb (Fig. 5.13).
Approximately two-thirds of ganglia in the lower limb are found on the foot, the most common sites being the dorsolateral aspect of the ankle and the hallux. The cysts contain a fluid similar to synovium thought to be derived from the adjacent tendon sheaths or joint capsules. Conservative treatment involves corticosteroid injection (with or without aspiration of the contents of the cyst); however, if the lesions become large and painful, surgical excision may be indicated. A retrospective review of 63 ganglion treatments by Pontious et al. reported a recurrence rate of 63% in those managed conservatively and 11% in those treated surgically. A very similar recurrence rate (61%) with conservative intervention was reported by Mallick et al.; however, the authors also stated that the recurrent lesions were far less symptomatic than the original lesions and required no further treatment.

Haemangiomas

Haemangiomas (also referred to as senile haemangiomas) are smooth, bright red, dome-like lesions that most commonly affect the head and neck but can also appear on the plantar surface of the foot or the toes (Fig. 5.15). The characteristic colour of the lesion is due to the presence of multiple dilated blood vessels. They rarely require treatment but can be removed by excision or electrodesiccation.

Keratoacanthomas

Most commonly observed on the head and neck of older people, keratoacanthomas are smooth, red, dome-like papules that range in size from a few millimetres to a few centimetres in diameter and can occasionally form on the foot (Fig. 5.16). Subungual lesions are often painful and tend to penetrate more deeply than lesions in other areas because of dorsal compression from the nail. In long-standing cases, the nail plate may separate from the nail bed at its distal edge and the distal phalanx may develop a crescent-shaped erosion easily visible on radiographs. Because it is often difficult to differentiate keratoacanthomas from squamous cell carcinomas, surgical excision is recommended.

Mucoid cysts

Also referred to as myxoid cysts or synovial cysts, mucoid cysts are soft, dome-like, oval lesions that form within the dermis and contain a straw-coloured, viscous fluid (Fig. 5.17). In the foot, mucoid cysts are most commonly located proximal to the nail fold and are thought to be caused by the herniation of the extensor tendon sheath or joint capsule. Large cysts may create difficulties with footwear and, if the lesion
penetrates the nail matrix, the nail plate may become dystrophic. Treatment involves cryotherapy, corticosteroid injection or excision.\textsuperscript{81}

**Naevi**

Naevi (‘moles’) are pigmented lesions that are highly variable in appearance, from firm, slightly elevated brown papules through to raised, verruciform nodules that may contain hair follicles. A brief summary of the more common presentations of naevi is provided in Table 5.3. Treatment is generally not necessary. However, all naevi need to be regularly monitored for changes in size, shape or colour, which may be indicative of malignant changes. It has also been demonstrated that one of the strongest predictors of malignant melanoma is a higher than average number of melanocytic naevi.\textsuperscript{82}

**Piezogenic pedal papules**

These common lesions develop around the periphery of the heel and appear as skin-coloured, soft herniations of fat when weightbearing (Fig. 5.18). Piezogenic pedal papules are thought to be protrusions of loculated fat extending through connective tissue irregularities in the dermis. The lesions are rarely symptomatic but may become painful in people who are overweight or in response to prolonged standing. Treatment involves the use of rigid heel cups to prevent lateral spread of the heel pad, or surgical excision.\textsuperscript{83}

**Stucco keratoses**

Commonly observed on the dorsum of the foot in older people, stucco keratoses are white to yellow, dry, scaly lesions up to 1 cm in diameter that can occasionally be peeled off the underlying skin (Fig. 5.19). In some cases the lesions may have a cauliflower appearance.\textsuperscript{84} The cause is unknown; however, a recent study reported the presence of human papilloma virus DNA in the lesions of an immunocompromised older patient.\textsuperscript{85} Treatment involves application
Calcaneal petechiae

Commonly referred to as black heel, calcaneal petechiae are benign, trauma-induced lesions typically located on the posterolateral aspect of the heel. The lesions are caused by lateral shearing of the papillary dermis, resulting in intraepidermal haemorrhage and the formation of multiple, pin-point macules, which may coalesce to form a dark irregular patch (Fig. 5.20). Calcaneal petechiae are most commonly found in young athletes; however, they do occur in older people and can be mistaken for verrucae or malignant melanoma. Often covered by or embedded in hyperkeratosis, the lesion may be cleared by scalpel debridement. However, no treatment is necessary and the lesions usually resolve over a period of weeks or months.87,88

Table 5.3 Common presentations of naevi

<table>
<thead>
<tr>
<th>Type</th>
<th>Appearance</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Junctional melanotic naevocellular naevus</td>
<td>Small (&lt;1 cm) circumscribed round brown macule with regular borders</td>
<td>Trunk, face, upper and lower limbs, palmar and plantar surfaces</td>
</tr>
<tr>
<td>Compound melanotic naevocellular naevus</td>
<td>Round, dome-shaped papule or nodule, may be papillomatous or hyperkeratotic</td>
<td>Trunk, face, scalp, upper and lower limbs</td>
</tr>
<tr>
<td>Dermal melanotic naevocellular naevus</td>
<td>Round, dome-shaped, skin coloured, tan or brown papule or nodule. Older lesions may be papillomatous or pedunculated</td>
<td>Face, neck, upper and lower limbs</td>
</tr>
<tr>
<td>Halo naevomelanocytic naevus</td>
<td>Oval or round brown papule with white ‘halo’ of hypomelanosis</td>
<td>Trunk</td>
</tr>
<tr>
<td>Blue naevus</td>
<td>Oval or round, dark blue to grey-black, firm papule or nodule &lt;1 cm</td>
<td>Dorsum of hands and feet</td>
</tr>
</tbody>
</table>

Figure 5.18 Piezogenic papules. (With permission from Dockery GL. Color atlas of foot and ankle dermatology. Philadelphia: Lippincott-Raven; 1999.)

Figure 5.19 Stucco keratoses. (Courtesy of Lloyd Reed, Queensland University of Technology.)
Over the past six decades, the incidence of skin cancer has dramatically increased throughout the world. In the USA, 1.8 million people were diagnosed with skin cancer in 2002, including 900,000 cases of basal cell carcinoma, 300,000 cases of squamous cell carcinoma and 53,000 cases of malignant melanoma. Incidence rates are even higher in countries with very high levels of sun exposure, such as South Africa and Australia. In addition to level of sun exposure, the key risk factors for skin cancer are a positive family history, fair complexion, presence of dysplastic naevi (atypical moles) or actinic keratoses and a higher than average number of naevi. Mortality rates associated with skin cancer are particularly high in men and increase markedly over the age of 60 years.

The foot is not a common site for the development of premalignant or malignant lesions, as footwear provides some protection from sun exposure. However, malignancies that do develop on the foot are subject to delayed or incorrect diagnosis, which may explain the higher mortality rate of foot lesions compared to lesions located elsewhere. It is therefore essential that all clinicians involved in the management of foot disorders thoroughly examine, monitor and document suspect lesions in older patients and provide timely referrals to dermatologists or oncologists where necessary. As stated in Chapter 3, the simple ABCD mnemonic (A = asymmetry, B = border irregularity, C = change in colour and D = increase in diameter) is a useful general rule for routine clinical assessment of lesions and has been found to be highly sensitive and specific in differentiating between benign and malignant lesions.

The following section provides an overview of some of the more common premalignant and malignant lesions that may develop on the older foot.

**Actinic keratoses**

Actinic keratoses, also known as solar dermatoses or senile keratoses, are the most common premalignant epidermal lesions in older people, affecting 45% of men and 35% of women aged over 65 years. The lesions are well circumscribed raised papules or plaques and have a dry, scaly surface. Although actinic keratoses most commonly affect areas of sun-exposed skin, such as the head, neck, face and arms, they can also develop on the legs and feet (see Fig. 5.21). These lesions should be carefully monitored as they may degenerate into squamous cell carcinomas. Indeed, because the rate of conversion is so high, a number of authors have argued that actinic keratoses are simply an early stage of squamous cell carcinoma and should be relabelled accordingly. Treatment involves topical application of 5-fluorouracil or diclofenac sodium, or destruction of the lesion using cryotherapy or electrodesiccation.
Arsenical keratoses

Arsenical keratoses are caused by exposure to inorganic arsenic compounds in medications (such as drugs used for psoriasis and bronchitis in the 1930s and 1940s), insecticides or drinking water, and appear as multiple discrete, yellow, punctuate round lesions on the palms and plantar surface of the foot (Fig. 5.22). Treatment involves the application of emollient creams and keratolytics. Oral administration of acitretin (a medication commonly used for psoriasis) in conjunction with intralesional injection of 5-fluorouracil has also been reported to be effective. As with actinic keratoses, arsenical keratoses can degenerate into squamous cell carcinomas.

Bowen’s disease

Bowen’s disease is an epidermal carcinoma sometimes referred to as squamous cell carcinoma in situ and is most commonly seen in women in the eighth decade of life. The lesion is a well-defined, raised, irregular plaque with superficial crusting that most commonly develops on sun-exposed areas of skin (Fig. 5.23). On the foot, the plantar surface is the most common site, although lesions have also been reported on the dorsum of the foot or between the toes. Although the lesion may become malignant, conversion to squamous cell carcinoma is rare (approximately 3% of cases). Treatment involves topical application of 5-fluorouracil, cryotherapy, electrodesiccation or surgical excision.

Basal cell carcinoma

With an overall lifetime risk of 30% of the Caucasian population, basal cell carcinoma is the most common form of skin cancer. The most common presentation, nodular basal cell carcinoma, starts as a small, dome-shaped nodule or papule that expands into an erythematous, blue-black lesion with a pearly translucent border. Other variants include cystic basal cell carcinoma, which has a lobulated appearance and may contain a clear fluid, pigmented basal cell carcinoma, which has a pigmented brown-black border, and superficial basal cell carcinoma, which is the most common type affecting the foot and appears as red plaque with an adherent scaly surface (Fig. 5.24). Treatment involves cryotherapy, surgical excision or radiotherapy. A recent Cochrane review of 19 trials concluded that both surgical excision and radiotherapy are effective, although surgical excision has a lower failure rate.
Squamous cell carcinoma

Squamous cell carcinoma is the second most common form of skin cancer, with 59% of cases occurring in people aged over 65 years. The lesion is a sharply demarcated, scaly or crusted, erythematous plaque most commonly found on the head and neck or other sun-exposed areas of the skin. Although foot involvement is rare (approximately 2% of cases), squamous cell carcinomas can develop on the dorsum of the foot, the heel, beneath the nail plate or interdigitally (Fig. 5.25). When the toes are affected, the condition can easily be misdiagnosed as an infection. Longstanding chronic ulcers, scars, non-healing verrucae and sinuses in older people may also undergo malignant changes and develop into a secondary form of squamous cell carcinoma (referred to as Marjolin’s ulcer). Because of the risk of metastasis, treatment involves wide surgical excision.

Malignant melanoma

The most lethal form of skin cancer, malignant melanoma comprises only 5% of all skin cancers but accounts for three-quarters of all skin-cancer-related deaths. Foot involvement is not common (fewer than 10% of cases), however the consequences of misdiagnosis are serious, with survival rates of primary melanoma of the foot and ankle being much lower than other lower limb sites. There are four main types of malignant melanoma: superficial spreading malignant melanoma, the most common form which appears as a flat plaque with an irregular border (Fig. 5.26), nodular malignant melanoma, which appears as a firm, blueberry-coloured nodule, lentigo maligna, a broad, brown lesion most commonly found on the head and neck, and acral lentiginous malignant melanoma, which are commonly misdiagnosed as subungual haematomas or verrucae. In the foot, the most commonly affected sites are the plantar surface, followed by the dorsum and beneath the nail plate. Treatment involves surgical excision and adjunctive chemotherapy.
The foot is a relatively common site for the development of skin lesions in older people. Many of these lesions are asymptomatic and may not require treatment, while other conditions are best managed by dermatologists. However, all foot-care specialists should be capable of establishing at least a provisional diagnosis of these conditions and providing informed referrals where necessary. Finally, although the foot is not a common site for the development of skin malignancies, all clinicians involved in the management of foot problems should have a high index of suspicion of non-healing or changeable lesions on the foot in older people.

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Nail disorders affect between 10% and 60% of people aged over 65 years of age,\(^1\) the most common complaints being fungal nail infection (onychomycosis), ingrown toenails (onychocryptosis) and abnormally thickened nails (onychauxis or onychogryphosis). While often dismissed as rather trivial complaints,\(^6\) nail disorders can be extremely painful and cause considerable difficulty with weightbearing tasks. In addition, onychomycosis and onychocryptosis can predispose to quite serious secondary infection in older people if left untreated.\(^7\)

Several changes in the structure and function of the nail apparatus increase the risk of developing nail disorders with advancing age. As stated in Chapter 2, the rate of growth of the nails decreases by up to 50% from adulthood to old age,\(^8,9\) due to a reduction in the turnover rate of keratinocytes and a reduction in size of the nail matrix itself. These changes are most likely due to age-related decline in peripheral blood supply,\(^10\) and possibly nutritional deficiencies. As a result of these changes, the nail plate in otherwise healthy older people becomes considerably thicker, and takes on a dull, opaque appearance.\(^11\) The increased thickness of the nail, in conjunction with exaggerated transverse curvature, increases dorsal pressure from footwear which in turn increases the likelihood of the nail penetrating the nail bed or distal pulp of the toe. Long-term damage to the nail bed may also give rise to the development of malignancies such as squamous cell carcinoma.\(^12-15\) The following chapter outlines the presentation and management of the most common disorders affecting the nail in older people. Premalignant and malignant skin tumours that may develop in the nail bed are covered in Chapter 5.
ONYCHOMYCOSIS

Onychomycosis, or fungal infection of the nail, is the most common of all nail disorders, affecting 2–13% of the general population, and between 24% and 41% of people over the age of 60 years. In addition to advancing age, risk factors for the development of onychomycosis include male sex, obesity, cigarette smoking, peripheral vascular disease, immunosuppression, concurrent interdigital tinea pedis, psoriasis and diabetes. Onychomycosis has been shown to have significant negative psychosocial effects and approximately half of all patients report pain, difficulty walking and footwear limitations due to the condition.

Onychomycosis is most commonly caused by infection from dermatophyte fungi, including Trichophyton, Epidermophyton and Microsporum species. By far the most common organism isolated from mycotic nails is Trichophyton rubrum, which has been reported to be present in between 67% and 82% of cases. However, a wide range of other fungi, yeasts and moulds have been isolated from fungal nails and there is evidence that onychomycosis in older people may be more likely to be caused by a combination of organisms. Scherer et al took samples from the hallux toenail in 450 people aged over 65 years and found that 30% had two or more organisms present, with 90% of these cases testing positive for saprophytes.

AETIOLOGY, CLASSIFICATION AND CLINICAL PRESENTATION

The presence of dermatophytes in the nail plate leads to a rapid growth of hyphae, which invade the nail through the longitudinal laminar spaces, penetrating keratinocytes and causing enzymatic degradation of keratin. Depending on the organism and region of the nail affected, this process manifests in four different patterns of infection. Distal subungual onychomycosis is the most common presentation and is caused by the fungus, usually Trichophyton rubrum, invading the distal edge of the nail, leading to a white–yellow discoloration of the nail and hyponychium. Proximal subungual onychomycosis, also caused by Trichophyton rubrum, is much less common and results from infection of the proximal nail fold, possibly triggered by trauma to the nail in immunocompromised patients. White superficial onychomycosis is commonly caused by Trichophyton mentagrophytes and, as the name suggests, leads to a superficial discoloration that coalesces to cover the entire nail plate (Fig. 6.1). The fourth presentation, Candidal onychomycosis, is caused by Candida albicans and has three subtypes: (1) Candida paronychia, characterised by swelling and erythema of the proximal and lateral nail folds, (2) Candida onycholysis, characterised by separation of the nail plate from the nail bed, and (3) Candida granuloma, characterised by thickening of the nail plate. Any of these four types of onychomycosis can further develop into total dystrophic onychomycosis, in which there is

Figure 6.1 Types of onychomycosis. A. Distal subungual. B. Proximal subungual. C. White superficial. (Courtesy of Lesley Newcombe, La Trobe University.)
little distinction between the nail plate and the underlying hypertrophic nail bed (Fig. 6.2).

Several non-dermatophyte moulds (such as Scopulariopsis, Acremonium, Aspergillus, Fusarium, Scytalidium and Alternaria) are also associated with onychomycosis. However, because they are rarely cultured in isolation, there is some question as to whether they cause nail infection or are merely secondary invaders. It is not possible to diagnose a mould-related nail infection from clinical signs and symptoms.

### ASSESSMENT AND DIAGNOSIS

Diagnosis of onychomycosis is based primarily on patient history and physical examination, to first rule out conditions that may mimic onychomycosis, such as psoriatic nails, onychogryphosis or trauma. However, the diagnostic accuracy of clinical observations of onychomycosis is less than 50%. Therefore, accurate diagnosis and selection of the most appropriate treatment requires culture of nail specimens. After cleansing the area with alcohol, full-thickness nail clippings from the actively infected region should be obtained using a scalpel or curette. It is important to ensure that the sample includes subungual debris, as this increases the likelihood of viable dermatophytes being transferred to the culture compared to specimens taken from the nail plate or nail bed.

Laboratory diagnosis of onychomycosis initially involves direct microscopy with 10% potassium hydroxide (KOH), which confirms the presence of dermatophytes by the observation of hyphae. Because the vast majority of fungal nail infections are caused by dermatophytes, a positive KOH result is often considered sufficient to initiate antifungal treatment. Isolation of the pathogen, however, requires 4–6 weeks of inoculation of the sample on Sabouraud’s agar or dermatophyte test medium, followed by microscopic examination. This second step may be particularly important in relation to suspected onychomycosis in older people, as a study of 450 specimens obtained from people aged over 65 years indicated a much higher incidence of saprophytes than dermatophytes (60% versus 24%), and a high proportion of mixed infections (30%).

### TREATMENT

Treatment of onychomycosis was revolutionised by the development of oral allylamine (terbinafine) in the 1990s, and there is a general consensus that oral treatment of onychomycosis is far more effective than topical therapy and should therefore be considered the gold standard of care. However, oral medication is costly and associated with frequent, though relatively minor, gastrointestinal side effects, and for these reasons oral treatment may not be appropriate in every situation. Furthermore, dystrophic onychomycosis can be highly resistant to both topical and oral treatment, so surgical intervention may be indicated in severe cases.

#### Topical treatments

A wide range of topical treatments have been used to treat onychomycosis, including the azoles (such as clotrimazole, ketoconazole and miconazole), allylamines (such as terbinafine), 2% miconazole nitrate solution, Gordochom solution (25% undecylenic acid and 3% chloroxylenol) and tea-tree oil (Terpinen-4-ol). These agents are often combined with 20–40% urea cream to facilitate penetration into the nail plate. However, very few randomised trials have been undertaken to evaluate the efficacy of these treatments. The Cochrane review published in 1999 found only two trials specific to toenail onychomycosis, neither of which provided evidence of efficacy compared to a placebo.

Since the publication of the Cochrane review, there has been considerable interest in three topical medications – terbinafine, amorolfine and ciclopirox. However, with the exception of ciclopirox, no placebo-controlled trials have so far been undertaken. Terbinafine, which became available as both an oral...
and topical medication in the early 1990s, has undergone extensive clinical trials in its oral form but relatively little evidence is available to support the efficacy of the topical cream. Amorolfine, a topical antifungal in lacquer form, has been shown in uncontrolled trials to be clinically effective in around 50% of cases of mild onychomycosis.49 Two randomised controlled trials of ciclopirox reported a mean mycological cure rate of 34% after 48 weeks of treatment, compared to 10% for the placebo.50 However, a recurrence rate of between 25% and 50% has been reported in patients after 1 year of treatment with ciclopirox.51 In response to the rather underwhelming evidence for the efficacy of topical agents, the British Association of Dermatologists has concluded that topical treatment is inferior to oral treatment and should only be considered in cases of very distal infection or for white superficial onychomycosis.45

**Oral treatments**

Several oral medications have been developed for the treatment of onychomycosis (Table 6.1). The first oral treatment for onychomycosis, griseofulvin, was isolated from *Penicillium griseofulvum* in 1939 and became available for clinical use in 1958.52 Griseofulvin is associated with headache and gastrointestinal adverse effects (and in rare cases hepatotoxicity) and may require up to 18 months to achieve mycological cure. As such, it has generally fallen out of favour because of the development of more effective medications. In 1969, two azoles ( clotrimazole and miconazole) were introduced, followed by econazole in 1974, ketoconazole in 1977 and itraconazole and fluconazole in early 1980s. Because of problems with oral administration of many azoles (such as poor absorption and hepatotoxic effects), only ketoconazole, itraconazole and fluconazole were fully developed into oral medications for onychomycosis.53 Ketoconazole, however, is generally only used for recalcitrant cases of onychomycosis caused by yeast infection.45

The most significant development in oral therapy, terbinafine, was discovered in 1974 and became widely used in the early 1990s.54,55 In contrast to griseofulvin and the azoles, terbinafine is fungicidal, achieving its effects by interrupting the biosynthetic pathway required to build the fungal cell wall. A systematic review of oral treatments for onychomycosis, based on 32 randomised controlled trials, concluded that a 12-week regimen of 250 mg of terbinafine per day is more effective than both griseofulvin and itraconazole,56 achieving mycological cure rates of between 70% and 80%. Terbinafine has also been shown to be more cost-effective than itraconazole, griseofulvin, fluconazole and ciclopirox.51 When prescribed for older people, it needs to be kept in mind that terbinafine has documented interactions with some antidepressants, antipsychotics, anticoagulants, beta-blockers and antiarrhythmic medications.52 However, a multicentre study of 1508 patients indicated that only 6% of those aged over 60 years reported serious adverse events associated with the use of terbinafine.57

Several studies have been conducted to evaluate the efficacy of combining topical and oral treatments, based on the rationale that the oral medications reach the nail through the nail bed while the topical agents penetrate the nail plate itself.58 Moderately improved cure rates have been reported for combinations of topical tioconazole plus oral griseofulvin, ciclopirox lacquer plus oral terbinafine, and amorolfine lacquer

<table>
<thead>
<tr>
<th>Drug</th>
<th>Mechanism of action</th>
<th>Antifungal activity</th>
<th>Dosage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Griseofulvin</td>
<td>Fungistatic</td>
<td>Dermatophytes, <em>Candida</em> Not effective against <em>Candida</em></td>
<td>750–1000 mg/day</td>
</tr>
<tr>
<td>Fluconazole</td>
<td>Fungistatic</td>
<td>Dermatophytes, <em>Candida</em>, some non-dermatophyte moulds such as <em>Aspergillus</em> and <em>Rhodotorula</em></td>
<td>450 mg/week</td>
</tr>
<tr>
<td>Itraconazole</td>
<td>Fungistatic</td>
<td>Dermatophytes, <em>Candida</em>, some non-dermatophyte moulds such as <em>Aspergillus</em>, <em>Scopulariopsis</em> and <em>Fusarium</em></td>
<td>200 mg/day</td>
</tr>
<tr>
<td>Terbinafine</td>
<td>Fungicidal</td>
<td>Dermatophytes, <em>Candida</em>, some non-dermatophyte moulds</td>
<td>250 mg/day</td>
</tr>
</tbody>
</table>
plus griseofulvin, terbinafine, itraconazole or fluconazole, compared to the oral medication alone. However, because of the increased complexity of the treatment regimen, compliance with combination therapy may be more difficult to achieve.

**Surgery**

Severely thickened, dystrophic onychomycosis may be extremely painful and resistant to both topical and oral treatment. In such cases, it may be necessary to consider surgical management, which involves complete avulsion of the nail under local anaesthetic, followed by topical and/or oral antifungals while the new nail grows back. It needs to be kept in mind, however, that longstanding cases of dystrophic onychomycosis may cause irreversible damage to the nail matrix, so there is no guarantee that the infection-free nail will be of normal shape or thickness. If dystrophic regrowth is considered likely, complete avulsion of the nail followed by matrixectomy is advisable. Methods for nail avulsion are described in the section on onychocryptosis later in this chapter.

**Preventing recurrence**

Recurrence of onychomycosis is very common, with between 20% and 50% of patients experiencing relapses within 5 years following an initially successful treatment. It is therefore essential that the older person or their carer be advised of strategies to prevent reinfection. Such strategies include discarding infected footwear and hosiery, avoiding barefoot activity in public places, keeping the feet cool and dry, wearing absorbent cotton socks, detecting and treating tinea pedis before it spreads to the nail and applying antifungal powder to footwear at least once per week. Footwear should also be carefully examined, as trauma to the nail by ill-fitting footwear may also trigger relapses.

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**ONYCHOCRYPTOSIS**

Onychocryptosis, also referred to as *unguis incarnatus*, *unguis aduncus* or simply *ingrown toenail*, is predominantly a condition that affects young adults but has been reported to occur in 5–10% of people aged over 65 years. Because of age-related reductions in peripheral vascular supply and the increased propensity to infection, onychocryptosis has potentially serious consequences such as ulceration and cellulitis. The condition develops when a spicule of nail penetrates the nail sulcus, leading to erythema, swelling and secondary infection. If left untreated, a pulp of overhanging hypergranulation tissue may develop that bleeds in response to minor trauma. At this stage, the condition can be exquisitely painful (Fig. 6.3).

**AETIOLOGY AND RISK FACTORS**

Surprisingly little research has been undertaken to evaluate the factors associated with the development of onychocryptosis, so much of our understanding of the condition is based on clinical observations. Factors thought to be associated with onychocryptosis include ill-fitting footwear, tight socks, hyperhidrosis, incurved/involuted nails, pronated foot type, hallux valgus, incorrect cutting of nails and variations in toe length. Three case-control studies have been undertaken. The most detailed study by Langford et al compared 50 cases with onychocryptosis of the hallux to 50 controls, and found that those with onychocryptosis had broader toes, decreased nail thickness, and increased eversion of the great toe when weightbearing. Gunal et al found that patients...
with onychocryptosis were more likely to have a hallux shorter than, or of equal length, to the second toe, with the so-called ‘Egyptian foot’ (hallux longer than the second toe) less likely to develop onychocryptosis. Finally, Pearson et al. assessed several aspects of nail anatomy (including thickness and curvature) in 23 cases and 23 controls but found no differences between the groups.

In addition to these proposed risk factors, onychocryptosis may develop secondary to several other disorders of the nail unit, including benign and malignant tumours of the nail bed, dystrophic onychomycosis, traumatic subungual haematomas and subungual exostosis. Several medications have also been reported to lead to onychocryptosis, including indinavir (a medication used in the treatment of HIV infection), oral retinoids, cyclosporin and oral antifungals. In each case, the medication appears to increase the risk of onychocryptosis by causing paronychia and promoting the development of hypergranulation tissue.

ASSESSMENT AND DIAGNOSIS

The diagnosis of onychocryptosis is straightforward, and is based on the classical signs and symptoms of redness and swelling of the toe and quite severe, sharp pain in response to lateral pressure. Most commonly, the lateral sulcus will be affected through compression from the second toe. Probing the sulcus of the affected side of the toe will often enable the localisation of the offending piece of nail and will assist in differentiating onychocryptosis from simple paronychia. Based on clinical signs and symptoms, the condition can be classified into three progressive stages. In stage 1, the toe appears red and swollen and there is pain on direct pressure to the nail and while walking. In stage 2, there is evidence of infection, slight pressure to the toe will cause considerable pain, and the patient may have difficulty walking. In stage 3, hypergranulation tissue has developed over the edge of the nail plate. While stage 1 onychocryptosis may be successfully managed with appropriate nail shaping and clearing subungual debris, stages 2 and 3 will generally require surgery.

There is generally no need for further diagnostic investigations prior to initiating treatment of onychocryptosis; however, if the nail is highly incurvated, a lateral hallux X-ray may be required to assess whether a subungual exostectomy is indicated. Footwear should also be thoroughly examined, as the wearing of shoes with a narrow toebox is likely to lead to recurrence.

TREATMENT

Conservative

Early stage onychocryptosis may be successfully managed by clearing the sulcus of hyperkeratotic debris (onychophosis), removing the offending spicule of nail with a scalpel and smoothing the edge of the nail with a file. This may be undertaken without anaesthesia; however, if the pain is severe, local anaesthesia may be necessary. Inserting a small piece of cotton wool or foam beneath the edge of the nail may prevent recurrence by slightly elevating the nail plate. In cases where the nail is being compressed against the adjacent toe, taping techniques or the use of foam toe spacers to separate the toes may also be useful (Figs 6.4, 6.5). Advice on appropriate nail cutting may assist in preventing recurrence.

Orthonyxia, the gradual correction of incurvated nails using bracing techniques, is no longer commonly used but may have a role in the prevention of onychocryptosis in older people for whom surgery is contraindicated. Several variations have been described in the literature. The simplest technique involves...
thoroughly clearing the nail sulcus of debris and then looping a short piece of 0.5 mm gauge stainless steel wire underneath the medial and lateral edges of the nail. A small loop is then shaped on the dorsal surface of the nail, and pliers are used to twist the loop. This exerts a dorsal force on the plantar medial and lateral edges of the nail, and a corresponding plantar force on the dorsal aspect of the nail plate, thereby reducing the convexity of the nail (Fig. 6.6). The brace is kept on for a month and regular reassessments and reapplications are necessary to maintain the correction.

Limitations of nail bracing include difficulties in affixing the wire to the nail, impingement from footwear, the possibility of trauma to the nail sulcus, the prolonged duration of treatment and high likelihood of recurrence. Furthermore, very few studies have been undertaken to assess the efficacy of nail bracing procedures. However, a recent non-randomised study by Harrer et al compared a nail bracing technique to nail avulsion surgery and found that those in the nail brace group were less likely to take time off work because of their foot problem and could return to wearing normal footwear earlier than those who had surgery. Recurrence rates were similar between the groups. Based on these results, the authors suggest that bracing should be considered as an effective alternative to surgery.

**Surgical**

Surgical intervention is often required for recurrent onychocryptosis, and more than 75 techniques have been described in the literature. Broadly speaking, two approaches are most commonly used in contemporary practice: incisional procedures (such as the Winograd, Frost, Zadik and terminal Syme techniques) and nail avulsion with phenolisation. Each approach has advantages and disadvantages; however, the most recent Cochrane systematic review of nine randomised controlled trials (with at least 6 months follow-up) concluded that nail avulsion combined with phenolisation is more effective than surgical excision in the treatment of ingrown nails.

Before considering surgical intervention, it is essential that the older patient’s vascular status be thoroughly assessed to ascertain their wound-healing potential. Although nail surgery is not contraindicated in older people, those with an ankle–brachial index of below 0.5 or toe pressures below 40 mmHg may be at risk of delayed healing and subsequent increased risk of infection. Similarly, diabetes is not a contraindication for nail surgery, provided the patient’s vascular status and blood glucose control are adequate. A report of 57 people with diabetes who had undergone phenol matrixectomy for onychocryptosis reported no serious adverse events.

The most commonly used excisional nail surgery techniques are the Winograd, Zadik and terminal Syme’s procedures. The Winograd procedure, first described in 1929, involves excising the medial or lateral nail sulcus and adjacent nail plate, bed and matrix to the depth of the proximal phalanx. The
wedge of tissue is removed, and any residual nail bed or matrix is removed with a curette. The original description of the technique suggested that the operative site should be left open to heal by primary intention; however, recent modifications recommend the use of sutures (Fig. 6.7). Reported recurrence rates when using this technique range from 11% to 27%. In 1950, Frost described a further modification of the Winograd procedure in which the incision is extended proximally (creating an L shape) to provide greater access to the nail matrix. However, tissue necrosis of the skin flap is a relatively common complication with this modification.

The Zadik technique was first described in 1950, and involves total nail avulsion and surgical removal of the nail matrix. The nail plate is lifted and removed with an elevator, and a full-thickness skin flap is created by making two oblique incisions from the medial and lateral corners of the nail fold. The flap is retracted to expose the nail matrix, which is removed to the depth of the proximal phalanx. The surgical site is then closed and the flap is sutured back into place (Fig. 6.8). Recurrence rates of between 27% and 50% have been reported in the literature.

Amputation of the distal half of the distal phalanx (commonly referred to as the terminal Syme’s procedure) was first described as a treatment for subungual exostosis by Lapidus in 1933 and as a treatment for onychocryptosis by Thompson & Terwilliger in 1951. A deep elliptical excision is made around the entire nail plate and nail matrix, just distal to the interphalangeal joint. The distal phalanx is removed with a bone saw distal to the insertion of the long extensor tendons, and the plantar flap is sutured to the line of the proximal incision (Fig. 6.9). Recurrence rates are reportedly lower than other surgical techniques; however, the postoperative appearance of the toe may be cosmetically unacceptable to many patients. For this reason, some authors consider the Syme’s procedure to be a radical approach that should only be employed when other treatments have failed.

The surgical techniques described above have been largely replaced by total or partial nail avulsion with phenolisation. This technique, first described by Boll in 1945 and used almost exclusively by podiatrists and chiropodists, is less invasive and has a far lower recurrence rate than excisional techniques. However, these benefits are slightly offset by an increased risk of postoperative infection. The technique is performed under local anaesthesia and tourniquet, and involves separating the nail plate from the nail bed using an eponychium retractor, removing the offending portion of nail (from the medial sulcus, lateral sulcus or both) proximal to the eponychium and applying liquefied phenol (C₆H₅OH, carbolic acid) with a cotton wool bud to the nail matrix, sulcus and nail bed to prevent regrowth (Fig. 6.10). Reported recurrence rates range from 4% to 10%.
have been described, such as sodium hydroxide, negative galvanic current, cryosurgery and carbon dioxide laser. There is little evidence that these approaches offer any significant advantages over phenolisation.

Thorough postoperative management of the surgical site is an essential component of the treatment plan. Patients should be advised that some bleeding following the surgery is normal and necessary. The first redressing, generally undertaken 3–5 days following the procedure, should be performed under sterile conditions as the wound site is a potential avenue for infection. The patient should then be advised to undertake redressings every 5–7 days. Several different wound dressings have been recommended, including paraffin-impregnated gauze, hydrogels, topical antibiotic creams and alginates. However, a randomised controlled trial of three dressings (povidone iodine, an amorphous hydrogel and a control dressing of paraffin gauze) found no difference in healing times following phenol matrixectomy, with all three groups healing after 33–34 days. Similarly, a recent controlled trial of honey versus paraffin-impregnated gauze found no difference in healing times following phenol matrixectomy.

ONYCHAUXIS AND ONYCHOGRYPHOSIS

AETIOLOGY AND CLINICAL PRESENTATION

The term onychauxis refers to hypertrophy (thickening) of the nail plate (Fig. 6.11). This condition affects approximately 65% of older people and may be accompanied by onychophosis (the formation of keratotic tissue in the nail sulcus) and paronychia (inflammation of the tissues surrounding the nail plate). Onychauxis is thought to be caused by a range of factors, including subungual exostosis, a history of trauma to the nail, compression from footwear and reduced peripheral circulation. Onychauxis is also frequently observed in conjunction with onychomycosis. In older people, longstanding onychauxis is generally irreversible as permanent damage has
occurred to the nail bed and nail matrix. If left untreated, haematomas and ulcers may develop beneath the nail plate, which are potential avenues for infection (Fig. 6.12).

Onychogryphosis (also referred to as Ram’s horn nail or Ostler’s toe) is a condition in which the nail plate is grossly thickened and deformed. The nail appears yellow to dark brown and develops a curved or horn-like shape (Fig. 6.13). In severe cases, the nail may penetrate the soft tissue of adjacent toes. Onychogryphosis is caused by the same aetiological factors as onychauxis but is most likely to result from a major traumatic event such as severely stubbing the toe. This damages the nail matrix, causing it to produce nail in an irregular manner. Onychogryphosis may also result from long-term neglect of older people. Mohrenschlager et al\(^\text{112}\) reported a case of onychogryphosis in a 92-year-old woman, who was discovered in her home in a confused state and had not received any foot care for at least 2 years. Her nails were grossly thickened and elongated, and the nail had penetrated the second toe, leading to ulceration.

### TREATMENT

Treatment of onychauxis and onychogryphosis involves clearing the sulcus of keratotic debris and reducing the thickness of the nail with a file or motorized burr. Foam or silicon gel toe sleeves may help alleviate pressure from the toe, and footwear should be carefully examined for suitability and replaced if necessary. Total avulsion of the nail should be considered in symptomatic cases, as both conditions are indicative of permanent damage to the nail matrix and will invariably recur. However, because these conditions most commonly affect frail older people, surgical avulsion may not be viable. In such cases, non-surgical nail avulsion may be a useful alternative.
This requires the application of 40% urea cream to the nail plate, occluding the toe with adhesive tape or waterproof dressing. Dressing changes need to be undertaken twice per week. The urea cream gradually macerates the nail plate, enabling debridement of the entire nail.\textsuperscript{113–115}

**SUBUNGUAL EXOSTOSIS AND OSTEOCHONDROMA**

Subungual exostosis is an uncommon benign tumour of trabecular bone that most commonly develops on the distal phalanx of the hallux (Fig. 6.14).\textsuperscript{116} The aetiology is not well understood; however, repetitive trauma to the toe is thought to lead to periostitis and an outgrowth of cartilage that eventually ossifies.\textsuperscript{110} Clinical observations suggest that subungual exostoses may be associated with hallux limitus or rigidus, because of the compensatory hyperextension of the interphalangeal joint making the distal pulp of the toe more susceptible to compression from footwear.\textsuperscript{11} The presence of the exostosis may cause the nail plate to become incurvated or elevated at its distal edge and, in severe cases, the nail plate may become eroded and the nail bed ulcerated.\textsuperscript{117} At this stage, the condition may be difficult to differentiate from onychocryptosis or subungual melanoma; however, no cases of malignant degeneration of exostoses have been reported.

Osteochondromas are benign tumours that have a similar clinical presentation to subungual exostoses, although men are affected more than women, the growth rate of the tumour is somewhat slower and, in rare cases, osteochondromas may undergo malignant degeneration. Radiographically, osteochondromas appear dome-like and exhibit a characteristic radiolucent cap of hyaline cartilage, in contrast to the broad trabecular tuft of bone observed in subungual exostoses.\textsuperscript{118}

Both subungual exostoses and osteochondromas need to be differentiated from malignant tumours of the nail bed, including squamous cell carcinoma, basal cell carcinoma and malignant melanoma.\textsuperscript{119} Although uncommon, the diagnosis of these tumours is often delayed and many patients with malignant subungual lesions are inappropriately treated. Indeed, a study of 52 patients who were ultimately diagnosed with subungual malignant melanoma indicated that almost half had undergone nail avulsion or cauterisation procedures.\textsuperscript{120} Clinical observations of loosening of the nail plate, chronic inflammation and draining of the lesion are indicative of an underlying malignancy and should prompt referral for biopsy.\textsuperscript{121}

Treatment of subungual exostoses and osteochondromas involves protecting the toe from further trauma by the use of foam or silicon gel toe sleeves and addressing the potential contribution of ill-fitting footwear. If these conservative measures fail, surgical excision may be necessary, which involves partial or total nail avulsion (depending on the size and location of the lesion), followed by removal of the growth using a bone chisel.\textsuperscript{122} Following surgical excision, recurrence is uncommon (less than 10%),\textsuperscript{123} however, distal onycholysis and subungual hyperkeratosis may develop postoperatively.

**CLUBBING OF THE NAILS**

Exaggerated longitudinal curvature of the fingernails and toenails (Fig. 6.15) is believed to have been first reported by Hippocrates, giving rise to the alternative nomenclature *Hippocratic nails*. The condition is also referred to as *acrophy*, *digital clubbing* and *dysacromelias*. By definition, a nail is considered to be ‘clubbed’ if the angle formed by the intersection of the proximal nail fold and the nail plate (known as the angle of Lovibond) is 180° or greater.\textsuperscript{124} Clubbed
nails are occasionally hereditary but more commonly develop in association with a wide range of systemic conditions, including respiratory disease (e.g. tuberculosis, emphysema, bronchiectasis and lung cancer), cardiovascular disease (e.g. congestive heart failure and bacterial endocarditis) and gastrointestinal diseases (e.g. ulcerative colitis and chronic diarrhoea). The mechanism responsible for clubbing of the nails is uncertain. One theory suggests that excessive vasodilation of vessels develops around the nail, which leads to the formation of an oedematous, bulbous nail bed and subsequent nail plate curvature. An alternative view suggests that chronic excess platelet formation associated with some systemic diseases leads to the development of large clumps of platelets, which become embedded in peripheral vessels in the fingers and toes, leading to increased capillary permeability and hypertrophy of surrounding soft tissues. Irrespective of the underlying cause, clubbed nails are generally not painful and therefore rarely require treatment.

**YELLOW NAIL SYNDROME**

Yellow nail syndrome is an uncommon condition characterised by the triad of thickened, incurvated yellow nails (both fingernails and toenails), lymphoedema and respiratory disease (including asthma, tuberculosis, pleural effusion, bronchiectasis, chronic sinusitis and chronic obstructive pulmonary disease) (Fig. 6.16). The condition has also been reported in association with several other conditions, including rheumatoid arthritis, various forms of cancer, thyroid disease and sleep apnoea. The nail dystrophy associated with the syndrome is thought to be due to lymphatic obstruction in the nail region, which causes a markedly reduced growth rate (as slow as 0.12–0.27 mm/week), with an inversely proportional increase in nail thickness. Because of the increased bulk of the nail plate, development of onychophosis and paronychia is common, and complete separation of the nail plate (onycholysis) may occur. The condition can be easily differentiated from nail discoloration associated with onychomycosis, as the discoloration is generally uniform and the nail plate is considerably harder.

Yellow nail syndrome is treated in the same manner as onychauxis and onychogryphosis, the goal of therapy being to reduce the thickness of the nail and prevent any subungual breakdown from developing. There is preliminary evidence that oral vitamin E or oral zinc supplementation may improve the appearance of the nail; however, the mechanism is not fully understood. Interestingly, spontaneous recovery of yellow nail discoloration and dystrophy has been noted in response to treatment for other comorbidities, including rheumatoid arthritis, diabetes mellitus and tuberculosis.
Pincer nails (also referred to as omega nails or trumpet nails) are a form of involuted/incurvated nail deformity in which the transverse curvature of the nail plate becomes more pronounced distally, producing an almost cylindrical structure around the distal pulp of the toe (Fig. 6.17). Pincer nails frequently present with onychocryptosis, onychophosis and paronychia, and in severe cases the nail bed may become ulcerated. The aetiology of pincer nails is not fully understood. It has been hypothesised that the formation of osteophytes on the proximal aspect of the distal phalanx causes a widening of the proximal nail matrix but, because the unaffected distal nail matrix is narrower, the nail plate assumes a conical shape as it progresses distally. Symmetrical pincer nails affecting several toes have been shown to be a hereditary trait associated with a congenital deviation of the nail matrix and nail bed. Most cases, however, affect the hallux nails and develop secondary to tumours of the nail bed, dystrophic onychomycosis, psoriasis and, less commonly, use of beta-blockers. Lateral pressure from footwear (particularly in association with hallux valgus) has also been postulated as a potential cause. Pincer nails may also be indicative of gastrointestinal malignancy.

Symptomatic pincer nails are managed in essentially the same manner as onychocryptosis caused by involuted/incurvated nails. However, surgical management of long-standing pincer nails will often require total rather than partial nail avulsion, and many cases will require excision of the underlying exostosis or hypertrophied nail bed. Haneke has also described a reconstructive procedure for severe pincer nail deformity which involves bilateral partial nail avulsion with phenolisation, followed by excision of the exostosis and insertion of rubber tubes into the lateral nail grooves, which are sutured to pull the nail folds apart (Fig. 6.18).

A vast range of systemic diseases may manifest as nail plate abnormalities. Although nail changes are rarely specific enough to form a definitive diagnosis, nail plate changes may provide useful clues to the presence of an undiagnosed systemic condition, or at least provide some level of confirmation of an established diagnosis. The most obvious clue to an underlying systemic aetiology is the involvement of multiple nails or both fingernails and toenails.

Common nail plate changes associated with systemic disease include onycholysis (separation of the nail plate from the nail bed at its distal end), splinter haemorrhages (extravasation of blood from blood vessels in the nail bed), koilonychia (concave or spoon-shaped nails), Hippocratic nails (clubbing of the nail), leukonychia (white discoloration of the nails), Beau’s lines (transverse ridges across the nail plate caused by temporary slowing or cessation of nail growth),
paronychia (inflammation of tissues around the nail) and pitted nails (formation of multiple superficial pits on the dorsal surface of the nail plate, most commonly observed in people with psoriasis – Fig. 6.19). Systemic conditions associated with each of these nail plate disorders are listed in Table 6.2.

Similarly, several systemic medications, particularly antibiotics and cancer chemotherapeutic drugs, may produce characteristic nail changes. The most common changes to the nail caused by systemic medications are onycholysis and alterations in pigmentation of the nail (including longitudinal and transverse banding, and colour changes in the lunula). As with changes associated with systemic disease, nail changes associated with medications are rarely specific enough to establish causality but may assist in differential diagnosis. Systemic medications associated with common nail plate disorders are listed in Table 6.3.

**SUMMARY**

Nail disorders, particularly onychomycosis and onychocryptosis, are very common in older people and can be highly debilitating. Fortunately, advances in pharmacological treatment of onychomycosis have vastly improved cure rates of this previously recalcitrant condition. Furthermore, there is now sound evidence for the efficacy of nail avulsion with phenolisation for onychocryptosis and, provided there is...
Table 6.2 Nail abnormalities associated with systemic disease

<table>
<thead>
<tr>
<th>Onycholysis</th>
<th>Splinter haemorrhages</th>
<th>Koilonychia</th>
<th>Hippocratic nails</th>
<th>Leukonychia</th>
<th>Beau's lines</th>
<th>Paronychia</th>
<th>Pitted lines</th>
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Summary

- Gout
- Hyperalbuminuria
- Hypoparathyroidism
- Myocardial infarction
- Psoriasis
- Renal disease
- Epilepsy
- Hepatic disease
- Hyperparathyroidism
- Psoriatic nails
- Reiter’s syndrome
- Pemphigous vulgaris
### Table 6.3 Nail abnormalities associated with systemic medications

<table>
<thead>
<tr>
<th>Onycholysis</th>
<th>Splinter haemorrhages</th>
<th>Pigmented bands (longitudinal)</th>
<th>Pigmented bands (transverse)</th>
<th>Leukonychia</th>
<th>Beau’s lines</th>
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sufficient vascular supply to enable healing, age should be no barrier to the provision of this effective treatment strategy. Finally, all foot-care specialists should be aware of the myriad of systemic conditions and medications that may produce changes in the appearance of the nails of older people.

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Peripheral vascular disorders and foot ulceration

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As outlined in Chapter 2, ageing is associated with several changes in the structure and function of the peripheral vascular system, including an increase in the stiffness of the arterial walls and a decrease in the diameter of large veins. The overall effect of these changes is a progressive reduction in arterial blood flow and venous return, which increases the risk of developing circulatory disorders of the lower limb. Indeed, there is an approximate twofold increase in risk of developing peripheral arterial disease for every 10 year increase in age,1 and age is an independent risk factor for conditions associated with venous insufficiency, such as varicose veins2,3 and venous ulcers.4

Although foot-care specialists will not necessarily always be involved in the direct medical management of peripheral vascular diseases affecting the lower limb, they will frequently be presented with foot and ankle manifestations of these conditions. The following chapter provides a brief overview of common circulatory disorders which may manifest in the older foot and discusses the management of associated foot ulcers in older people. Vascular assessment of the lower limb (including wound assessment) is covered in Chapter 3.

ARTERIAL DISORDERS

PERIPHERAL ARTERIAL DISEASE

Peripheral arterial disease (PAD) is a chronic arterial occlusive disease of the lower limb caused by atherosclerosis, the thickening of the intima of large arteries, which results in a reduction in vessel diameter and subsequent reduction in peripheral blood flow.5,6
PAD affects between 11% and 34% of people aged 65 years and over. Key risk factors for the development of PAD include cigarette smoking, diabetes mellitus, hypertension and dyslipidaemia. Symptoms of PAD usually have gradual onset and indeed a large number of cases are asymptomatic. The classical early presentation of ischaemically induced pain is intermittent claudication, a tight, cramping pain in the calf region (or, less commonly, in the thigh, buttocks or foot) that occurs when walking and is relieved by rest. In more advanced PAD, a similar cramping pain may develop in bed (referred to as night cramps), as the heat of the bedclothes increases the oxygen demand of the legs. The most severe form of ischaemic pain occurs in the absence of any physical activity (referred to as rest pain) and indicates that the arterial supply of the limb cannot even meet quiescent metabolic requirements. At this stage, the limb is so severely ischaemic that ulceration and/or gangrene may develop – a state commonly referred to as critical limb ischaemia, which implies that, if limb perfusion cannot be improved, there is a significant risk of limb failure and subsequent amputation.

The characteristic features of chronic arterial occlusion in the lower limb include symptoms of numbness, paraesthesias and coldness, and signs of skin atrophy, rubor and lack of hair (Fig. 7.1). In longstanding cases the foot may become ulcerated or gangrenous. Arterial ulcers affecting the foot most commonly develop on the apices of the toes, the medial and lateral malleoli and the plantar aspect of the heel, and typically have a well circumscribed, ‘punched-out’ appearance with a dry base and little exudate (Fig. 7.2). Gangrene initially appears as non-blanching cyanosis, followed by the formation of a black eschar of the involved part (Fig. 7.3). Gangrene is commonly accompanied by severe rest pain and represents severely compromised peripheral arterial supply requiring surgical intervention.

The management of PAD involves smoking cessation, the use of statin medications to treat dyslipidaemia and antiplatelet therapy to reduce the risk of myocardial infarction and cerebrovascular accident. A recent review of 42 trials involving 9706 patients concluded that the risk of cardiovascular events was reduced by 23% in those taking aspirin daily. Walking programs of at least 6 months duration have also been shown to increase the distance walked before the onset of claudication. The underlying mechanism responsible for the beneficial effect of exercise is not fully understood but is thought to be related to an increase in collateral blood flow, decreased blood viscosity and improved metabolism of skeletal muscle.

Surgical management of PAD is considered when intermittent claudication or rest pain is severe enough to impair normal daily activities and involves revascularisation (bypassing the affected vessel using grafting techniques) or angioplasty (the insertion of intraluminal stents to expand the affected vessel/s). Vessel patency following femoropopliteal and femorotibial bypass grafts ranges between 56% and 92% after 1
year and between 12% and 80% after 5 years.21 When revascularisation fails or there is a significant amount of gangrenous or necrotic tissue present, amputation is considered as a last resort.6

ACUTE ARTERIAL OCCLUSION

An acute arterial occlusion is an abrupt interruption of blood flow within a peripheral artery caused by direct trauma or, more commonly, due to a thrombus or embolus. Acute thrombosis generally develops in an already partially occluded artery and may therefore be asymptomatic. In contrast, most emboli originate in the heart due to atrial fibrillation and the subsequent blockage of a normal or partly diseased artery is much more likely to be acutely symptomatic.

A limb subjected to acute embolic occlusion will typically become extremely painful, pale, cold and numb distal to the site of the occlusion. However, in some patients, collateral blood supply may cause the foot to appear red while dependent,22 which may mimic the appearance of cellulitis or an acute attack of gout. Furthermore, an acutely ischaemic foot in a patient with diabetes may feel warm. Because of these potential diagnostic challenges, it has been suggested that clinicians should have a high index of suspicion of acute arterial occlusion in all older patients who present with an acutely painful foot.22

Acute arterial occlusion is a vascular emergency, as critical ischaemia may develop within a period of hours. Treatment involves thrombolytic therapy alone or in conjunction with embolectomy, a surgical procedure in which the embolus is extracted using a balloon catheter.23

VASOSPASTIC DISORDERS AND CONDITIONS RELATED TO COLD EXPOSURE

Raynaud’s phenomenon

Raynaud’s phenomenon, first described in 1888,24 is a condition characterised by recurring episodes of discolouration of the fingers and toes initiated by exposure to cold (Fig. 7.4). The condition is generally classified as primary (Raynaud’s disease) when no underlying cause can be identified, or secondary (Raynaud’s syndrome) when it is associated with an underlying disorder.25 Conditions known to be associated with Raynaud’s phenomenon are listed in Table 7.1. The reported prevalence of Raynaud’s phenomenon ranges from 3% to 21%, with women being more frequently affected than men (a ratio of approximately 4 : 1).26–28

The pathophysiology of Raynaud’s phenomenon is poorly understood but is thought to be related to increased plasma viscosity and overactivity of the sympathetic nervous system, leading to reduced capillary blood flow.29,30 The classic presentation is that of an initial white discoloration of the fingers or toes, followed by a blue discoloration due to deoxygenation of the blood and a then a final red discoloration due to reactive hyperaemia, accompanied by a throbbing sensation. Longstanding cases may also develop chronic paronychia and ulceration of the apices of the
Diagnosis is primarily based on clinical signs and symptoms (Table 7.2).  

Raynaud’s phenomenon is frequently a transient disorder. Two recently published follow-up studies of 7 and 14 years duration demonstrated that a large proportion of cases (64% and 33%, respectively) had completely resolved without treatment. In persistent cases, however, several treatments have been trialled, including oral medications (such as nifedipine, reserpine, and prazosin), topical agents (such as nitroglycerin ointment), conditioning and biofeedback, and, in severe cases, lumbar sympathectomy. The reported efficacy of these treatments is highly variable and no systematic reviews have so far been undertaken. However, several authors suggest that nifedipine, a potent vasodilator, is currently the treatment of choice and is effective in approximately two-thirds of cases.

**Acrocyanosis and livedo reticularis**

Acrocyanosis and livedo reticularis are uncommon, benign vasospastic conditions that rarely require treat-
Arterial disorders

Acrocyanosis is characterised by a persistent cyanosis of the extremities (including fingers, toes and ears) that is exacerbated by cold. The aetiology is unknown, although secondary forms of the condition may develop in several connective tissue disorders. Livedo reticularis is characterised by a mottled discolouration of blue-purple rings surrounding central regions of pallor on the arms and legs and is thought to be caused by vasospasm of dermal arterioles (Fig. 7.5).

**Erythema pernio**

Erythema pernio (also referred to as *pernio syndrome*, *perniosis* or, more commonly, *chilblains*) is a condition characterised by inflammatory lesions of the skin (particularly the fingers, toes, nose and ears) caused by exposure to cold (Fig. 7.6). The prevalence of the condition is unknown but it is thought to be more common in women and is particularly prevalent in people who are frequently exposed to cold, damp conditions, such as dairy farmers, soldiers and ‘horsey women’ (sic). Erythema pernio appears to be in overall decline because of improvements in household heating and changes in work practices. Acute lesions, which appear as erythematous, purplish papules up to 1 cm in diameter, develop within 24 hours of the initial exposure and will generally resolve within a number of weeks. Chronic lesions are typically very itchy, purplish plaques, which may ulcerate in response to repeated scratching by the patient. The severity of the lesions increases in the presence of concurrent PAD.

The normal response to cold involves arteriolar constriction in conjunction with capillary dilatation, resulting in a loss of deoxygenated blood and subsequent build-up of metabolites in the interstitial spaces. This process is reversed when the body part is rewarmed; however, for reasons that are still not fully understood, people who develop chilblains exhibit a prolonged period of vasoconstriction. It is thought that the sustained presence of metabolites is responsible for the characteristic burning and itchiness associated with the condition. Histological and histochemical studies of lesions reveal high levels of T cells, macrophages and necrotic keratinocytes, indicative of an inflammatory process in both the epidermis and dermis.

Over the years, a plethora of treatments have been proposed for the management of chronic erythema pernio, including calciferol, vitamin D, histamine injection, corticosteroids, bandaging to induce reactive hyperaemia, electrotherapy, ultraviolet light, thyroxine and nicotinic acid. Very few of these treatments have been rigorously evaluated and the only consensus in the literature is that prevention, by avoiding cold exposure, is preferable to treatment. Contemporary management of chilblains involves appropriate wound management of the lesions, the application of topical vasodilator ointments (such as those containing methyl salicylate) and, for symptomatic relief, paraffin wax baths. Oral nifedipine has been found to be effective in a large-scale placebo-
controlled trial, both as a treatment and for prophylaxis.58

**Trench foot and immersion foot**

Trench foot and immersion foot are cold-induced injuries resulting from exposure of the feet to non-freezing cold (0–15°C) and wet conditions for several days. The vasospasm resulting from cold exposure leads to hypoxia and capillary stasis, resulting in cyanosis and, in severe cases, superficial gangrene. As the name suggests, trench foot developed in soldiers during trench warfare in the First and Second World Wars. Immersion foot is essentially the same condition but was first described in shipwreck survivors in the Second World War and was also common in the Korean and Vietnam wars.59 Treatment involves pain relief, limb elevation, gradual rewarming of the limb and management of skin breakdown.

Although these conditions are now primarily of historical interest, several cases have been reported in homeless people60,61 and neglected older people.62 Williams et al63 described a recent case of a 79-year-old man who had suffered a fall and was discovered by his neighbours two days later soaked in urine. Upon admission to hospital, he was hypothermic and dehydrated, and both feet had developed severe ischaemia that eventually required amputation (Fig. 7.7).

## CHRONIC VENOUS INSUFFICIENCY

### EPIDEMIOLOGY AND RISK FACTORS

Chronic venous insufficiency (CVI) can be broadly defined as a cluster of pathologies that result from the inability of the peripheral veins to return venous blood to the heart in an efficient manner. Although prevalence estimates vary widely, because of variations in sample characteristics and case definitions, it has been estimated that CVI affects up to 40% of women and 17% of men at some stage in their life.4,64 The most common manifestations of CVI – varicose veins and venous ulceration – affect approximately 30%,65,66 and 3%,67–69 of older people, respectively. In addition to increasing age, risk factors for the development of CVI include female sex,4,66,70,71 increased height,2,72 obesity,4,66,72 family history,2,4,65,71 pregnancy,3,4,72 occupations that involve prolonged periods of standing2,4,65,72 and low socioeconomic status.74 The chronic and recurrent nature of conditions associated with CVI – particularly venous ulceration – has a considerable impact on health-care expenditure. For example, it has been estimated that, in the UK, the management of venous legs ulcers costs approximately £400 million each year and accounts for half of the workload of community nurses.75

### PATHOPHYSIOLOGY AND CLINICAL PRESENTATION

In the normal limb, relaxation of the calf muscles results in deep veins filling with blood from the superficial veins via perforating veins. Contraction of the calf muscles when walking compresses the deep veins, thereby assisting in the return of deoxygenated blood to the heart. This system ensures that deoxygenated blood is shunted from superficial to deep veins and from distal to proximal veins.76 In people with CVI, however, this system is impaired, leading to an increase in blood pressure in the superficial veins (venous hypertension). This may be due to either an obstructed
outflow (caused by thrombosis), inefficient inflow (caused by valvular dysfunction leading to reflux) or a combination of the two.77

CVI may present in a wide variety of ways, including telangiectasia (spider veins), varicose veins, oedema, hyperpigmentation and venous ulceration (Figs 7.8–7.10). Typical symptoms of CVI include heaviness, swelling, aching, restless legs, cramps, itching and tingling.78 Diagnosis of CVI is relatively straightforward and is based primarily on clinical observations and physical examination (Ch. 3); however, more detailed vascular laboratory examinations are required for presurgical planning and where deep vein thrombosis is suspected.79

**TREATMENT**

Treatment of CVI includes external compression (via compression bandages or elastic stockings), management of skin integrity (including application of emollients and appropriate wound care), sclerotherapy (the injection of sodium tetradecyl or polidocanol to increase vein stiffness via vein wall fibrosis) and surgical management (including ligation and stripping or venous reconstruction).80–82 Compression bandaging, in conjunction with limb elevation and exercise, has been shown to be effective in the management of venous ulceration, achieving healing rates of up to 75% over a period of 6 months.75 However, recurrence rates as high as 69% have been reported after 12 months.83 Although the choice of wound dressing does not appear to be a major consideration,84 the latest Cochrane review of 22 trials indicated that multilayer bandaging systems (involving combinations of tubular bandage and wool) were more effective than a single layer of bandage.85 Management of venous
ulcers is described in more detail later in this chapter.

The relative benefits and indications for sclerotherapy versus surgery in the management of varicose veins are unclear. Sclerotherapy is generally recommended for smaller varicose veins below the knee, but has traditionally been associated with a relatively high rate of recurrence. The most recent Cochrane review of nine trials concluded that there was insufficient evidence to preferentially recommend sclerotherapy or surgery, however, there is some evidence of better long-term outcomes with surgery.

**LYMPHOEDEMA**

**EPIDEMIOLOGY AND CLASSIFICATION**

Lymphoedema is a condition characterised by the accumulation of fluid in the limbs, caused by the inability of the lymphatic system to adequately drain lymph from interstitial spaces. Two broad categories are recognised: *primary* (or *idiopathic*) lymphoedema, also referred to as Milroy’s disease, and *secondary* lymphoedema. Primary lymphoedema is most commonly present at birth, although it may occasionally develop later in life (cases developing after the age of 35 years are referred to as **lymphoedema tarda**). The cause is unknown. Secondary lymphoedema occurs in response to obstruction of the lymphatic system caused by trauma, surgical intervention, invasive tumours, radiotherapy or filarial infestation.

The prevalence of lymphoedema in the general community is largely unknown. Studies undertaken in women who have undergone axillary surgery for breast cancer indicate incidence rates in the range of 25–28%. A recent survey conducted in several community health services in the UK identified 823 patients over a 4 week period, with 1 in 200 aged over 65 years. Women were also more commonly affected than men, even after accounting for cases related to breast cancer surgery.

**CLINICAL PRESENTATION**

The diagnosis of lymphoedema is based on patient history, clinical signs and symptoms. Swelling most commonly affects the limbs but may also develop in the abdomen and the face and results in the gross enlargement of the affected body part (Fig. 7.11). The swelling is generally more resistant to compression (i.e. non-pitting) than venous oedema and the trophic changes commonly associated with venous insufficiency (such as ulceration and hyperpigmentation) are generally absent. However, advanced cases may exhibit hardening of skin and subcutaneous tissues. Approximately 50% of people with lymphoedema report pain or discomfort, most commonly described as aching or a sensation of heaviness. Laboratory investigations are not commonly undertaken; however, lymphoscintigraphy, a semiquantitative technique in which technetium-99m is injected into the interdigital space of the foot or hand and the drainage patterns are observed, has been shown to be of use in differentiating between lymphoedema and other forms of oedema. A characteristic ‘honeycomb’ pattern of the subcutaneous tissues has also been observed with magnetic resonance imaging.

**TREATMENT**

There is no known cure for lymphoedema. Management of the condition involves attempts to reduce congestion (such as compression bandaging, exercise and manual lymph drainage), maintenance of skin integrity and pliability, and, in advanced cases, surgery. There is very little evidence for the effectiveness of physical therapy for lymphoedema, as only three small trials have been conducted, with variable results. Compression bandaging in conjunction with supportive hosiery appears to be more effective than hosiery...
alone, while the addition of manual lymph drainage confers no additional benefit over compression bandages alone. Surgery involves resecting affected subcutaneous tissue and underlying fascia, followed by skin grafting to cover the defect. Because of significant problems with postoperative wound healing and poor cosmesis, surgery is only performed in severe cases where the bulk of the limb impairs mobility and severely impacts on quality of life.

**FOOT ULCERATION**

As outlined in Chapter 2, ageing is associated with several changes to the structure and function of the skin, including a marked loss of collagen and elastin, leading to increased skin fragility and a reduction in the number of Langerhans and mast cells, which reduces the speed and intensity of the inflammatory response to infection. These changes, in conjunction with the reduction in peripheral blood flow to the lower limb, increase the likelihood of tissue damage and impair the ability of the skin to heal. Subsequently, many older people endure chronic, recurrent lower limb ulceration, which can be highly debilitating and difficult to manage successfully. Nevertheless, if managed appropriately, ulcers in older people have a similar chance of complete resolution to those in younger people.

The following section provides a brief overview of the prevalence, clinical presentation and management of foot wounds in older people. For more detailed information, the reader is referred to recent textbooks that specifically address wound management, including Krasner et al’s *Chronic wound care* and Foster’s *Podiatric assessment and management of the diabetic foot*.

**EPIDEMIOLOGY OF FOOT ULCERS IN OLDER PEOPLE**

The prevalence of venous leg ulceration and diabetic foot ulceration has been studied in some detail, however, the overall prevalence of skin breakdown affecting the foot in older people has received relatively little attention in the literature. The most representative community study of 784 Americans aged over 65 years reported that 4% exhibited ‘foot ulcers’; however, no attempt was made to determine their underlying aetiology. A recent prevalence study of lower limb ulcers (including the foot) in the UK indicated that 43% of ulcers were venous, 15% were mixed (i.e. venous and arterial causes), 4% were arterial, 2% were related to diabetes and 2% were induced by pressure bandages. The remaining 35% were considered to be multifactorial.

Risk factors for the development of foot ulcers vary depending on the primary underlying aetiology. Arterial ulcers are strongly related to the severity of PAD, whereas venous ulcers, as discussed previously, have a more complex set of risk factors (including female sex, increased height, obesity, family history, pregnancy, occupations that involve prolonged periods of standing, and low socioeconomic status). Diabetic foot ulcers also have a complex pathophysiology, with the key risk factors being loss of protective sensation, foot deformity, absent foot pulses or reduced ankle–brachial index, elevated plantar pressures and the presence of plantar callosities. Pressure ulcers, which commonly affect the sacrum but can also develop on the malleoli or posterior aspect of the heel, develop in institutionalised older people confined to bed and are frequently associated with several underlying comorbidities and nutritional deficiencies.

**CLINICAL PRESENTATION OF FOOT ULCERS**

Foot ulcers tend to have a characteristic appearance depending on the primary underlying aetiology and, in most cases, differentiating between ulcer types is relatively straightforward when the appearance of the wound, patient history and physical examination are taken into account. The following section briefly describes the typical appearance of different types of foot ulcers, and a summary is provided in Table 7.3.

**Arterial ulcers**

Arterial foot ulcers most commonly affect the dorsum of the toes, the interdigital spaces or the heel, and typically have a ‘punched-out’ appearance with well-defined edges and a dry base with very little exudate (Fig. 7.2). The edges of the wound may be oedematous, and the surrounding skin dry and fissured. Arterial ulcers tend to be painful, and leg elevation will exacerbate symptoms because of the reduction in peripheral blood flow. Other signs of reduced arterial supply (such as pulselessness, pallor and paraesthesia) will frequently be evident. In older people, arterial ulcers are often triggered by trauma, such as ill-fitting...
footwear or stubbing the toes. Several cases of toe ulceration have also been recorded in people receiving compression therapy for venous insufficiency.123

**Venous ulcers**

Venous ulcers most commonly affect the ‘gaiter’ region between the calf and the heel, (typically overlying the medial or lateral malleoli)15 and are generally shallow with irregular, ‘shaggy’ borders and a substantial amount of exudate (Fig. 7.12). The base of the wound typically has a yellowish appearance, and necrosis is seldom present. The surrounding tissue is often oedematous and the skin hyperpigmented, and other characteristic signs of venous insufficiency (such as varicose veins and telangiectasia) will also be evident.124 In contrast to arterial ulcers, older people presenting with venous ulcers will generally have a reasonable peripheral arterial supply, with palpable pulses and warm surrounding skin. However, ulcers with a mixed arteriovenous aetiology will present with a combination of these features.

**Diabetic ulcers**

Diabetic foot ulcers most commonly develop in sites of elevated weightbearing pressure – most commonly the metatarsal heads but also the toes and plantar aspect of the heel (Fig. 7.13).125 The ulcers are usually deep and may be undermined, with callused surrounding skin. The limb will feel cool and will exhibit pallor on elevation and a dusky rubor when dependent. Because of the significant role of neuropathy, diabetic foot ulcers are generally painless, although

### Table 7.3 Characteristics of different types of foot ulcers

<table>
<thead>
<tr>
<th></th>
<th>Arterial</th>
<th>Venous</th>
<th>Diabetic</th>
<th>Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Location</strong></td>
<td>Dorsum of toes</td>
<td>Malleoli</td>
<td>Plantar metatarsal heads</td>
<td>Posterior aspect of heel</td>
</tr>
<tr>
<td></td>
<td>Interdigital spaces</td>
<td></td>
<td>Plantar hallux</td>
<td>Malleoli</td>
</tr>
<tr>
<td></td>
<td>Heel</td>
<td></td>
<td>Plantar heel</td>
<td></td>
</tr>
<tr>
<td><strong>Shape</strong></td>
<td>Round</td>
<td>Irregular</td>
<td>Round</td>
<td>Round, or irregular if large</td>
</tr>
<tr>
<td><strong>Depth</strong></td>
<td>Deep</td>
<td>Shallow</td>
<td>Shallow to deep</td>
<td>Shallow to deep</td>
</tr>
<tr>
<td><strong>Margins</strong></td>
<td>Smooth, Well-defined</td>
<td>Irregular</td>
<td>Smooth</td>
<td>Variable</td>
</tr>
<tr>
<td><strong>Base</strong></td>
<td>Dry</td>
<td>Exudative</td>
<td>Variable</td>
<td>Variable</td>
</tr>
<tr>
<td><strong>Surrounding skin</strong></td>
<td>Pale and cold</td>
<td>Hyperpigmented</td>
<td>Callused</td>
<td>Variable</td>
</tr>
<tr>
<td><strong>Pain</strong></td>
<td>Severe Increases with limb elevation</td>
<td>Minimal to moderate Decreases with limb elevation</td>
<td>Generally painless</td>
<td>Often painful</td>
</tr>
<tr>
<td><strong>Pedal pulses</strong></td>
<td>Diminished or absent</td>
<td>Generally present</td>
<td>Diminished or absent</td>
<td>Variable</td>
</tr>
</tbody>
</table>

*Figure 7.12 Venous ulcer. (Courtesy of Nikki Frescos, La Trobe University.)*
some patients may report burning pain and paraesthesia.\textsuperscript{126} Diabetic ulcers are frequently infected and may present with purulent, foul-smelling exudate. Differentiating between arterial, venous and diabetic foot ulcers is straightforward and is informed primarily by patient history, ulcer location and clinical tests of sensory status (e.g. Semmes–Weinstein monofilaments or vibration perception threshold testing).\textsuperscript{15}

**Pressure ulcers**

Pressure ulcers (also referred to as \textit{decubitus ulcers}) result from long-term, unrelieved compression of the skin against an external surface. Such ulcers most commonly develop in older people with severely restricted mobility, such as older people confined to bed or those who require wheelchairs. The posterior aspect of the heel and medial and lateral malleoli are the most common lower limb sites (Fig. 7.14). The appearance of pressure ulcers is highly variable because of the high prevalence of comorbidities in older people in long-term care, and in many cases may mimic other types of chronic wound. The key to differentiating pressure ulcers from other types of wound is to identify the cause of the compression, such as pressure from a mattress or bedclothes, a poorly fitting prosthesis or an ineffective wheelchair cushion.\textsuperscript{127}

**WOUND MANAGEMENT**

Management of foot wounds should be primarily directed towards addressing the underlying aetiology, e.g. surgical revascularisation procedures to increase blood supply to the limb for arterial ulcers\textsuperscript{128} and reducing venous stasis via compression bandaging techniques or surgical management of incompetent perforator veins for venous ulcers.\textsuperscript{124} Although local wound management is important, there is a general consensus that ulcers are far more likely to heal if the underlying cause is appropriately managed. Furthermore, as outlined in Chapter 3, documenting a thorough social history is essential to the management of foot ulcers in older people in order to establish the practicality of ongoing self-management by the older person in their home environment.

The following section outlines the key components of wound management and discusses the available evidence pertaining to the efficacy of local wound care interventions.
Cleansing the wound

The first step in managing a wound is to clear the area of debris, exudate or any foreign bodies that may impair healing. Traditionally, this has been achieved by the application of antiseptic solutions; however, this has fallen out of favour because of concerns that antiseptic application may be cytotoxic and thus impair healing.\(^\text{129}\) Contemporary practice favours the use of isotonic saline solution; however, there is little evidence that saline offers any significant advantages over tap water.\(^\text{130}\) For pressure ulcers, there is limited evidence that Vulnopur, a saline spray containing aloe vera, silver chloride and decyl glucoside, improves healing compared to isotonic saline. However, studies comparing saline to tap water have reported no significant differences in healing times of pressure ulcers.\(^\text{131}\)

Debridement

Debridement refers to the removal of devitalised or contaminated tissue from a wound until underlying healthy tissue is exposed. This is undertaken in order to fully ascertain the true dimensions of the wound, to allow drainage of exudate and to allow swabs to be taken to assess for wound infection. Debridement can be achieved by mechanical methods (e.g. scalpel reduction, vigorous swabbing or larval therapy) or non-mechanical methods (e.g. the application of proteolytic enzyme preparations, polysaccharide beads or hydrogels).\(^\text{132}\) Debridement is considered to be particularly important in the management of diabetic foot ulcers.

The most recent Cochrane review\(^\text{133}\) reported that five randomised controlled trials have been undertaken to assess the efficacy of debridement in diabetic foot ulcers: three pertaining to hydrogels, one addressing surgical debridement and one of larval therapy. The results of these studies indicate that hydrogels are significantly more effective than simple gauze dressings; however, surgical debridement and larval therapy showed no significant benefit. The efficacy of debriding calluses surrounding diabetic foot ulcers has not been rigorously evaluated; however, several studies have shown that forefoot plantar pressures reduce by between 25% and 60% following callus debridement,\(^\text{134-136}\) which is likely to be beneficial to ulcer healing.

Dressing the wound

Deciding which dressing to apply to a wound can be quite a difficult task, a task that is made even more daunting by the vast number of options available. Indeed, it has been estimated that there are currently over 30 companies offering over 300 different wound dressings.\(^\text{137}\) Unfortunately, the conduct of rigorous clinical studies to assess the efficacy of wound dressings has lagged behind the rate of product development, so, in many cases, evidence to support the use of individual dressings is sorely lacking. Nevertheless, it is certainly true that various dressings function quite differently and that some may be more appropriate than others for particular situations. The basic fea-
tures of the ‘ideal’ wound dressing are outlined in Table 7.4.138

Broadly speaking, there are eight main types of wound dressings. The following descriptions are taken from Nelson & Bradley139 and are based on the British National Formulary definitions:

- **Wound dressing pads**: includes knitted viscose dressings and gauze dressings that are applied directly to the wound
- **Tulle dressings**: either non-medicated (e.g. paraffin gauze dressing) or medicated (e.g. containing povidone iodine or chlorhexidine)
- **Semi-permeable film dressings**: semi-permeable transparent films that allow gaseous exchange but are impervious to bacteria
- **Hydrocolloid dressings**: occlusive dressings that contain a hydrocolloid matrix with elastomeric and adhesive substances attached to a polymer base. The hydrocolloid liquefies on contact with wound exudate, producing a moist environment for wound healing to take place. These dressings seal the wound and are impervious to gas, bacteria and liquid
- **Hydrogels**: consist of a starch polymer and up to 80% water. They have the ability to absorb wound-exudate or rehydrate, depending upon their composition and the degree of exudation of the wound
- **Alginate dressings**: also included in the hydrogel group, derived from seaweed and come in the form of a loose, fibrous rope or pad. The calcium ions in the dressing interact with sodium ions within wound exudate to produce a fibrous gel. The gel provides a moist wound environment that allows gaseous exchange and provides a barrier to contamination

- **Bead dressings**: absorb exudate, wound debris and microorganisms by capillary action either into the beads or into the matrix between the beads
- **Foam dressings**: can be applied as sheets or as a liquid that expands to fill the wound-cavity.

Several authors have suggested that the primary factor upon which to base dressing selection is the degree of wound exudate.140 For low exudative wounds, alginate dressings are recommended, while for highly exudative wounds (such as venous ulcers), absorbent dressings such as hydrocolloids or foams are preferable. However, there is currently limited evidence that wound dressing selection has a significant impact on ulcer healing rates. For arterial ulcers, only one inconclusive trial of ketanserin ointment has been undertaken.139 Venous ulcers have been studied in more detail, with 42 randomised controlled trials evaluating hydrocolloids (n = 23), foams (n = 6), alginates (n = 4), hydrogel dressings (n = 6) and a group of miscellaneous dressings (n = 3).84 For the majority of dressing types, however, there is insufficient data to enable strong conclusions to be made, and a meta-analysis indicated no significant difference in healing rates between hydrocolloid dressings and simple, low-adherent dressings. Clearly, there is a considerable need for more research to assess the efficacy of different wound dressing products.

### Pressure relief

Pressure relief is particularly important in the management of diabetic foot ulcers and pressure ulcers. For diabetic foot ulcers, pressure reduction can be achieved by callus debridement, padded hosiery, orthoses, custom or extra-depth footwear and casts (Fig. 7.15).141 Four randomised controlled trials have been conducted to assess the efficacy of pressure relieving devices for diabetic foot ulcers: three for ulcer prevention and one for ulcer treatment. The results of these studies indicate that custom footwear in conjunction with orthoses is more effective in preventing ulcers than standard care, and that total contact casting is more effective in healing ulcers than simple wound dressings.142 However, there appears to be no significant difference in ulcer healing rates between simple cushioning insoles and those designed to redistribute pressure away from ulcerated sites.

<table>
<thead>
<tr>
<th>Table 7.4 Features of an ideal wound dressing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allows excess exudate to be removed from the wound surface</td>
</tr>
<tr>
<td>Provides a moist micro-environment</td>
</tr>
<tr>
<td>Is free of contaminants</td>
</tr>
<tr>
<td>Easy to change</td>
</tr>
<tr>
<td>Does not cause trauma when removed</td>
</tr>
<tr>
<td>Leaves no dressing material in the wound after removal</td>
</tr>
<tr>
<td>Reduces ulcer pain</td>
</tr>
<tr>
<td>Hypoallergenic</td>
</tr>
<tr>
<td>Acts as a semi-permeable membrane</td>
</tr>
<tr>
<td>Impermeable to microorganisms</td>
</tr>
<tr>
<td>Provides thermal insulation</td>
</tr>
</tbody>
</table>
The efficacy of pressure relief in relation to pressure ulcers has received considerable attention in the literature. Two main approaches have been trialed in the hospital or long-term care setting: regular turning of patients to reduce the duration of loading and the use of specialised cushions, beds and mattresses to reduce the magnitude of loading. Pressure relieving devices fall into two broad categories: those that simply disperse the pressure more evenly (referred to as constant low pressure devices, CLPDs), and those that mechanically vary the pressure through the use of inflatable pockets within the mattress (referred to as alternating pressure devices, APDs). The most recent review of 41 trials concluded that foam alternatives to the standard hospital mattress and the addition of sheepskin covers can reduce the incidence of pressure ulcers; however, the relative merits of CLPDs and APDs are unclear. Furthermore, there was insufficient evidence to draw conclusions on the value of seat cushions or limb protectors. The relevance of these findings to pressure ulcers affecting the foot are uncertain, as no differentiation between ulcer locations was considered and most ulcers were located on the sacrum. Interestingly, one trial of a proprietary device consisting of a vinyl boot with a built-in foot cradle and inflatable chamber reported a trend towards a higher rate of ulceration compared to elevation of the heels using a standard hospital pillow.

Compression therapy

Compression therapy is considered an essential component of venous ulcer management, as the primary cause of the trophic disturbance is superficial venous hypertension resulting from valvular incompetence. Compression is achieved by bandaging or hosiery, or a combination of the two. There are two main types of compression therapy: true compression, which involves the use of elastic materials that exert high pressure at rest and lower pressure in response to muscle contraction, and support, which involves the use of inelastic materials that exert low pressure at rest and higher pressure in response to muscle contraction. Compression systems can be classified accord-
ing to the amount of pressure they exert at the ankle (Table 7.5). The more severe the venous insufficiency, the greater the pressure required.

Before considering compression therapy for venous ulcers, it is essential that the patient’s ankle–brachial index (ABI) be assessed in order to evaluate the arterial supply to the lower limb. As a general rule, patients with an ABI of 0.8–1.0 are suitable candidates for high compression, those with an ABI of 0.5–0.8 should be provided with low compression and those with an ABI less than 0.5 should not be provided with compression therapy, as there is a risk of exacerbating existing limb ischaemia. Indeed, several cases of toe ulceration associated with the application of compression bandages have been reported.123

The most recent Cochrane review of 22 trials concluded that compression is considerably more effective than no compression when treating venous ulcers, that elastic compression is more effective than inelastic support, and that multiple-layered high compression is more effective than single-layer compression.85 Approximately 65–70% of venous ulcers will heal within 6 months if compression therapy is used.15 No trials have compared compression versus no compression for preventing venous ulcers. However, there is some evidence for greater efficacy of high compression versus low compression, and indirect support can be derived from observations that patients who do not wear compression hosiery are more likely to experience a recurrence of their ulcer.146

### Table 7.5 Types of compression therapy

<table>
<thead>
<tr>
<th>Type</th>
<th>Pressure applied at ankle</th>
<th>Indication/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compression stockings</td>
<td></td>
<td>Varicose veins</td>
</tr>
<tr>
<td>Class 1</td>
<td>14–17 mmHg</td>
<td>Varicose veins</td>
</tr>
<tr>
<td>Class 2</td>
<td>18–24 mmHg</td>
<td>Severe varicose veins</td>
</tr>
<tr>
<td>Class 3</td>
<td>25–35 mmHg</td>
<td>Prevention of venous ulcers</td>
</tr>
<tr>
<td>Class 3a</td>
<td>14–17 mmHg</td>
<td>Varicose veins</td>
</tr>
<tr>
<td>Class 3b</td>
<td>18–24 mmHg</td>
<td>Severe varicose veins</td>
</tr>
<tr>
<td>Class 3c</td>
<td>25–35 mmHg</td>
<td>Prevention of venous ulcers</td>
</tr>
<tr>
<td>Class 3d</td>
<td>Up to 60 mmHg</td>
<td>Severe varicose veins</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Prevention of venous ulcers</td>
</tr>
</tbody>
</table>

**Topical negative pressure**

Topical negative pressure (TNP), also referred to as subatmospheric pressure therapy, vacuum sealing technique, vacuum assisted wound closure and sealed surface wound suction, is a relatively recent form of therapy for managing foot ulcers that involves the application of an airtight dressing and suction pump to exert a negative pressure across the wound surface. TNP is thought to be accelerate wound healing by assisting with the removal of exudate and increasing local blood flow.147 Only two small trials have evaluated the effectiveness of TNP on chronic wound healing: one involved a range of chronic wounds and the other specifically focused on diabetic foot ulcers. Both trials indicated that TNP was superior to saline gauze dressings, although the sample sizes were small.148

**Hyperbaric oxygen therapy**

Hyperbaric oxygen therapy involves placing the patient in a compression chamber, increasing the environmental pressure within the chamber and administering 100% oxygen for several hours. By doing so, the partial pressure of oxygen supplied to the tissues is vastly increased, which is thought to be beneficial to wounds by reducing tissue hypoxia.149 Five trials have so far been undertaken: four involving diabetic foot ulcers and one involving venous ulcers. Pooled data analysis of three of the diabetic foot ulcer
trials indicated that hyperbaric oxygen therapy reduced the risk of major amputation by almost 70% compared to usual care; however, there was no effect on minor amputation rates. Patients treated with a sham treatment were twice as likely to have unhealed ulcers after 1 year than those who received the active treatment. For venous ulcers, hyperbaric oxygen therapy conferred a small benefit in relation to wound size reduction at 6 weeks, but no effect was observed at the 18-week follow-up. Overall, it would appear that hyperbaric oxygen therapy may have some value in the prevention of major amputations; however, issues associated with access and cost-effectiveness currently preclude its wider clinical use.

**Therapeutic ultrasound and short-wave diathermy**

Therapeutic ultrasound involves the application of high-frequency sound waves to the body, which are thought to stimulate wound healing via cavitation (the formation of microscopic vibrating cavities in tissues), increased uptake of calcium ions by fibroblasts, the release of serotonin from platelets and the release of histamine from mast cells. Seven trials have been undertaken to assess the effectiveness of ultrasound in the management of venous ulcers: four compared ultrasound therapy with sham ultrasound and three compared ultrasound therapy with standard treatment. Although there was a trend towards increased healing rates in the ultrasound groups, none of the trials found a difference in healing rates between any of the therapies. Similarly, three trials of ultrasound for pressure ulcers (including two comparing ultrasound with a sham ultrasound and one comparing ultrasound plus ultraviolet light to laser and standard treatment) found no evidence of benefit associated with the use of ultrasound.

Short-wave diathermy (SWD) refers to the application of the non-ionising form of radiation (from the radio wave portion of the electromagnetic spectrum) to tissues and has been used for wound healing since the 1940s. The electrical stimulation is thought to have a direct effect on the proliferation and migration of fibroblasts in damaged tissue. Only three randomised controlled trials have been undertaken: two comparing the use of SWD with sham therapy and one comparing SWD with topical treatments. Only one trial found a difference in healing rates between SWD and sham therapy; however, this difference was not statistically significant. Based on these results, it was concluded that there is no solid evidence that SWD is beneficial in the management of venous ulcers.

**Dietary supplements**

Vitamins and trace elements are known to be important for wound healing, and several case-control studies have shown that people with chronic leg ulcers have significantly lower serum levels of vitamins A and C and the trace minerals zinc and iron. Zinc is considered to be particularly important, as it has anti-inflammatory effects on phagocytic cells and is necessary for the function of a number of enzymes and hormones. In response to these observations, several trials of oral zinc sulphate supplementation have been undertaken in people with venous ulcers. Overall, there is no solid evidence of a beneficial effect of treatment with zinc sulphate on the number of ulcers healed. Similarly, no firm conclusions could be reached pertaining to efficacy of nutritional interventions in healing pressure ulcers, although one study has shown that the provision of a multivitamin and mineral supplement is effective in preventing pressure ulcers in critically ill older people admitted to hospital.

**Pentoxifylline**

Pentoxifylline is an oral medication that increases microcirculatory blood flow and oxygenation of tissues, possibly by increasing fibrinolytic activity and by decreasing blood viscosity and platelet aggregation. Nine trials have been conducted to ascertain the effectiveness of pentoxifylline in the management of venous ulcers. Pooling eight trials that compared pentoxifylline with placebo (with or without compression therapy) demonstrated that pentoxifylline is more effective than placebo in terms of complete ulcer healing or significant reduction in ulcer size, and pentoxifylline plus compression is more effective than placebo plus compression. Pentoxifylline therefore appears to be an effective adjunct to compression bandaging for treating venous ulcers.

**Skin grafting**

Skin grafting is generally only considered in the management of chronic, recurrent ulcers that have failed to respond to other conservative treatment approaches. Broadly speaking, there are three types of skin graft:
autografts (skin taken from another part of the body of the patient), allografts (skin taken from another person) and xenografts (skin taken from another species, most commonly from pigs). More recently, a fourth category – bioengineered human skin equivalents – has become available; these are products that consist of a matrix embedded with collagen, fibroblasts and keratinocytes derived from various sources, including neonatal foreskins and bovine skin. The actual mechanism of action of these products is unclear but is thought to be related to the stimulation of growth factors and cytokines within the wound.

A recent review of nine trials of skin grafting for venous ulcers indicated that a bilayer bioengineered human skin equivalent used in combination with compression bandaging was more effective than a simple dressing. Several recent trials have also reported promising results with the use of bioengineered human skin equivalents in the management of non-infected diabetic foot ulcers; however, it is essential that such a treatment is used in conjunction with debridement and offloading techniques. The cost-effectiveness of these products also needs to be carefully considered. A recent review of tissue-engineered biological dressings concluded that, while there is some evidence of efficacy, this intervention may be best viewed as a niche application where the likelihood of a positive outcome is high and the substantial costs can be justified.

Management of wound infection

The recognition and appropriate management of infection is an essential component of effective wound care, as the presence of infection significantly delays wound healing and failure to recognise local infection may result in serious complications such as osteomyelitis and sepsis. Wound infection is best viewed as a continuum, extending from contamination (defined as the presence of a stable population of microorganisms) through to colonisation (the presence of a population of replicating microorganisms without harm to the host) and eventually infection (the presence of a population of replicating microorganisms associated with damage to the host). Whether a wound progresses to infection is influenced by several factors related to the dose and virulence of the microorganisms present, the characteristics of the wound itself (e.g. the location, size, depth and duration of the wound, the presence of necrotic tissue or foreign bodies), underlying systemic conditions (particularly peripheral vascular disease and diabetes), the use of immunosuppressive medications and behavioural issues (including compliance with treatment, smoking, drug or alcohol use and diet).

The classic signs and symptoms of wound infection include pain, erythema, oedema, increased temperature and the presence of purulent exudate within the wound. However, there are additional signs of infection that are specific to chronic wounds, including serous exudate (thin watery fluid on the surface of the wound), pale, dusky or friable granulation tissue, the formation of smooth pockets at the base of the wound, and putrid odour. If clinical observations are suggestive of infection, further examinations, such as wound swabs or biopsy should be performed, particularly if the use of antibiotics is being considered. Both techniques have advantages and disadvantages. Although swab cultures are non-invasive and relatively simple to perform, the results are essentially qualitative and are often inconclusive in chronic
wounds. Wound biopsy is the gold standard technique for identifying the type and magnitude of infection; however, the process is invasive and may delay healing by damaging the wound bed. Management of infected wounds involves the use of topical antiseptics and/or systemic antibiotics, depending on the level of infection. A step-by-step algorithm recently published by the European Wound Management Association is a useful guide for clinical practice. A simplified version of the algorithm is shown in Figure 7.17, and the full position statement can be found at www.ewma.org. Depending on the foot specialist’s scope of practice, adequate management of infected wounds may require referral to a physician or multidisciplinary wound clinic. Generally speaking, wounds that are colonised or show signs of local infection can be managed with wound cleansing and debridement followed by appropriate topical iodine- or silver-based antiseptics, medical-grade honey or tea tree oil. However, wounds that show signs of spreading local infection or systemic infection do not appear to benefit from topical therapy and should therefore be managed with systemic antibiotics. Consensus regarding the selection of systemic antibiotics remains elusive but is informed by culture results, the microbial coverage of the antibiotic and clinical experience. The duration of therapy is also controversial and requires striking a balance.
between clinical effectiveness and the risk of developing microbial resistance. As a general rule, 2–4 weeks of antibiotic therapy is considered sufficient for most wounds.\textsuperscript{179}

**Evidence-based guidelines for comprehensive wound management**

In 2006, the Wound Healing Society facilitated the development of guidelines for the management of arterial,\textsuperscript{180} venous,\textsuperscript{181} diabetic\textsuperscript{182} and pressure\textsuperscript{183} ulcers based on the recommendations of an advisory panel of physicians, podiatrists, nurse clinicians and scientists. Inclusion of research findings in these guidelines was less strict than Cochrane systematic reviews (which are limited to randomised controlled trials); however, the level of evidence for each recommendation was documented. These guidelines are an excellent resource for foot care specialists, and the most relevant components are summarised in Tables 7.6–7.9.

**SUMMARY**

Disorders affecting the peripheral vascular system are extremely common in older people and foot-care specialists will frequently be presented with the lower

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**Table 7.6 Guidelines for the management of arterial ulcers**

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Level of evidence*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Restoration of blood flow by surgical revascularisation is the intervention most likely to lead to healing</td>
<td>II</td>
</tr>
<tr>
<td>Intermittent pneumatic leg compression improves blood flow and may be beneficial</td>
<td>II</td>
</tr>
<tr>
<td>Removal of necrotic tissue by debridement improves healing</td>
<td>II</td>
</tr>
<tr>
<td>In arterial ulcers with dry gangrene, debridement should not be used until arterial supply has been re-established</td>
<td>II</td>
</tr>
<tr>
<td>Neuroischaemic ulcers should be treated with a short course of systemic antibiotics even when clinical signs of infection are not present</td>
<td>II</td>
</tr>
<tr>
<td>Healing is enhanced with the use of topical warming, correction of dehydration and hyperbaric oxygen therapy</td>
<td>I</td>
</tr>
<tr>
<td>Topical antiseptics may be beneficial in the management of heavily colonised wounds</td>
<td>III</td>
</tr>
<tr>
<td>Ulcers of mixed aetiology (e.g. arterial ulcers associated with venous insufficiency) may benefit from (a) closely supervised compression therapy or (b) topical negative pressure</td>
<td>III</td>
</tr>
<tr>
<td>Closing the ulcer with a skin graft can assist wound healing</td>
<td>III</td>
</tr>
<tr>
<td>In arterial ulcers with sufficient arterial flow to enable healing, dressings that encourage moist wound healing are beneficial</td>
<td>II</td>
</tr>
<tr>
<td>Dry gangrene is best left dry until revascularisation has been performed</td>
<td>II</td>
</tr>
<tr>
<td>There is insufficient evidence for a beneficial effect from (a) ultrasound, (b) electrostimulation or (c) spinal cord stimulation</td>
<td>III, II, II</td>
</tr>
<tr>
<td>Pentoxifylline does not improve healing of arterial ulcers</td>
<td>I</td>
</tr>
<tr>
<td>Risk factor modification (smoking cessation, diabetes control and treatment of hypertension) can reduce arterial ulceration and recurrence</td>
<td>I</td>
</tr>
</tbody>
</table>

*Level I, meta-analysis of multiple randomised controlled trials (RCTs) or at least two RCTs or multiple laboratory or animal experiments with at least two clinical studies supporting the laboratory results; level II, at least one RCT and at least two significant clinical series or expert opinion papers; level III, suggestive data of proof-of-principle.
Table 7.7 Guidelines for the management of venous ulcers

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Level of evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 3 (most supportive) compression therapy improves healing, as does intermittent pressure in patients who cannot tolerate constant compression</td>
<td>I</td>
</tr>
<tr>
<td>Removal of necrotic tissue by debridement improves healing</td>
<td>I</td>
</tr>
<tr>
<td>Topical antiseptics may enhance healing in colonised, granulating wounds</td>
<td>I</td>
</tr>
<tr>
<td>Cellulitis should be treated with systemic Gram-positive bactericidal antibiotics</td>
<td>II</td>
</tr>
<tr>
<td>Systemic diseases, medications and nutrition should be assessed and managed</td>
<td>II</td>
</tr>
<tr>
<td>Wounds should be cleansed initially and at each dressing change with the minimum possible trauma</td>
<td>III</td>
</tr>
<tr>
<td>Select a dressing that promotes moist wound healing, minimises exudate and manages periwound maceration</td>
<td>I</td>
</tr>
<tr>
<td>Select a dressing that stays in place and minimises shear and friction</td>
<td>II</td>
</tr>
<tr>
<td>Skin grafting without addressing underlying venous disease is not a long-term solution</td>
<td>I</td>
</tr>
<tr>
<td>Endoscopic perforator surgery, superficial venous ablation or valvuloplasty can decrease re-ulceration if combined with compression therapy</td>
<td>I</td>
</tr>
<tr>
<td>Cytokine growth factors and oxygen-derived free radical scavengers have not yet been shown to be effective</td>
<td>I</td>
</tr>
<tr>
<td>Topical negative pressure may be beneficial</td>
<td>II</td>
</tr>
<tr>
<td>Laser therapy and ultrasound have not been shown to be effective</td>
<td>I</td>
</tr>
<tr>
<td>Sclerosing superficial veins as an adjunct to compression therapy is effective</td>
<td>III</td>
</tr>
<tr>
<td>Oral zinc supplementation is not effective</td>
<td>I</td>
</tr>
<tr>
<td>Patients with healed ulcers should continue to use compression therapy</td>
<td>I</td>
</tr>
<tr>
<td>Exercise to increase the function of the calf muscle pump are effective in ulcer prevention</td>
<td>III</td>
</tr>
</tbody>
</table>

*Level I, meta-analysis of multiple randomised controlled trials (RCTs) or at least two RCTs or multiple laboratory or animal experiments with at least two clinical studies supporting the laboratory results; level II, at least one RCT and at least two significant clinical series or expert opinion papers; level III, suggestive data of proof-of-principle.

Limb manifestations of vascular disease, particularly foot ulceration. A thorough lower limb vascular assessment is essential, as is the appropriate referral of patients to vascular specialists and endocrinologists for medical management of the underlying cause of the skin breakdown. Although the vast array of treatment options available for managing wounds can be somewhat perplexing, evidence from systematic reviews and recent clinical guidelines provides an excellent source of unbiased information regarding the efficacy of these interventions.
Table 7.8 Guidelines for the management of diabetic ulcers

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Level of evidence*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protective footwear should be prescribed</td>
<td>II</td>
</tr>
<tr>
<td>Off-loading techniques to relieve pressure can enhance healing</td>
<td>I</td>
</tr>
<tr>
<td>Removal of necrotic tissue by debridement improves healing</td>
<td>II</td>
</tr>
<tr>
<td>Topical antiseptics may enhance healing in colonised, granulating wounds</td>
<td>I</td>
</tr>
<tr>
<td>Systemic antibiotics for acute infections not confined to the wound are effective</td>
<td>II</td>
</tr>
<tr>
<td>Cellulitis should be treated with systemic Gram-positive bactericidal antibiotics</td>
<td>II</td>
</tr>
<tr>
<td>If osteomyelitis is suspected, appropriate diagnostic measures (sterile probe, X-rays, MRI, CT, bone scan) should be performed</td>
<td>II</td>
</tr>
<tr>
<td>Osteomyelitis is best treated by removal of infected bone and 2–4 weeks of antibiotics</td>
<td>II</td>
</tr>
<tr>
<td>Systemic diseases, medications and nutrition should be assessed and managed</td>
<td>I</td>
</tr>
<tr>
<td>Wounds should be cleansed initially and at each dressing change with the minimum possible trauma</td>
<td>III</td>
</tr>
<tr>
<td>Patients who fail to show a reduction in ulcer size by 40% or more after 4 weeks should be re-evaluated</td>
<td>II</td>
</tr>
<tr>
<td>Optimising glucose control improves wound healing</td>
<td>III</td>
</tr>
<tr>
<td>Select a dressing that promotes moist wound healing</td>
<td>III</td>
</tr>
<tr>
<td>Select a dressing that will manage wound exudate and protect periwound skin</td>
<td>I</td>
</tr>
<tr>
<td>Select a dressing that stays in place and minimises shear and friction</td>
<td>II</td>
</tr>
<tr>
<td>Achilles tendon lengthening may improve healing</td>
<td>II</td>
</tr>
<tr>
<td>Patients with ischaemia should be considered for revascularisation</td>
<td>II</td>
</tr>
<tr>
<td>Platelet-derived growth factor is effective in treating neurotrophic foot ulcers</td>
<td>I</td>
</tr>
<tr>
<td>Cytokine growth factors have not yet been found to be effective</td>
<td>I</td>
</tr>
<tr>
<td>Topical negative pressure may be beneficial</td>
<td>I</td>
</tr>
<tr>
<td>Electrical stimulation may be beneficial</td>
<td>I</td>
</tr>
<tr>
<td>Hyperbaric oxygen therapy reduces amputation rates in patients with ischaemic diabetic ulcers</td>
<td>I</td>
</tr>
<tr>
<td>Patients with healed diabetic ulcers should use protective footwear to prevent recurrence</td>
<td>II</td>
</tr>
<tr>
<td>Foot care and daily inspection of the feet reduces recurrence</td>
<td>II</td>
</tr>
</tbody>
</table>

*Level I, meta-analysis of multiple randomised controlled trials (RCTs) or at least two RCTs or multiple laboratory or animal experiments with at least two clinical studies supporting the laboratory results; level II, at least one RCT and at least two significant clinical series or expert opinion papers; level III, suggestive data of proof-of-principle.

CT, computed tomography; MRI, magnetic resonance imaging.
Table 7.9 Guidelines for the management of pressure ulcers

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Level of evidence*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remove pressure from ulcer site and establish a repositioning schedule</td>
<td>II</td>
</tr>
<tr>
<td>Elevating the head of the bed increases shear and should be avoided where possible</td>
<td>III</td>
</tr>
<tr>
<td>Pressure-reducing surfaces are more effective than standard hospital mattresses</td>
<td>I</td>
</tr>
<tr>
<td>Avoid doughnut-like devices</td>
<td>III</td>
</tr>
<tr>
<td>Assess patient nutrition and encourage supplementation where necessary</td>
<td>II</td>
</tr>
<tr>
<td>Removal of necrotic tissue by debridement improves healing</td>
<td>I</td>
</tr>
<tr>
<td>Obtain bone biopsy in cases of suspected osteomyelitis</td>
<td>II</td>
</tr>
<tr>
<td>Confirmed osteomyelitis should be treated with bone debridement and antibiotics</td>
<td>I</td>
</tr>
<tr>
<td>Systemic diseases and medications should be assessed and managed</td>
<td>II</td>
</tr>
<tr>
<td>Wounds should be cleansed with mild soap and water with minimum trauma</td>
<td>II</td>
</tr>
<tr>
<td>Select a dressing that promotes moist wound healing</td>
<td>I</td>
</tr>
<tr>
<td>Select a dressing that manages wound exudate and protects periwound skin</td>
<td>I</td>
</tr>
<tr>
<td>Select a dressing that stays in place and minimises shear, friction, skin irritation and pressure</td>
<td>II</td>
</tr>
<tr>
<td>Consider surgical closure for chronic pressure wounds</td>
<td>II</td>
</tr>
<tr>
<td>Growth factors may be beneficial</td>
<td>II</td>
</tr>
<tr>
<td>Topical negative pressure may be beneficial for ulcers that fail to heal with conventional therapy</td>
<td>I</td>
</tr>
<tr>
<td>Electrical stimulation may be beneficial for ulcers that fail to heal with conventional therapy</td>
<td>I</td>
</tr>
<tr>
<td>Hyperbaric oxygen therapy has not been shown to be effective</td>
<td>I</td>
</tr>
</tbody>
</table>

*Level I, meta-analysis of multiple randomised controlled trials (RCTs) or at least two RCTs or multiple laboratory or animal experiments with at least two clinical studies supporting the laboratory results; level II, at least one RCT and at least two significant clinical series or expert opinion papers; level III, suggestive data of proof-of-principle.

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Disorders of the toes

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HALLUX VALGUS

Hallux valgus (also referred to as hallux abductovalgus) is a common condition affecting the forefoot in which the first metatarsophalangeal joint is progressively subluxed as a result of lateral deviation of the hallux and medial deviation of the first metatarsal. The condition is frequently accompanied by a painful soft tissue and osseous prominence on the medial aspect of the first metatarsal head, commonly referred to as a ‘bunion’ (Fig. 8.1). As the deformity progresses, the lateral displacement of the hallux interferes with the normal alignment and function of the lesser toes, resulting in hammer toe or claw toe deformities, altered weightbearing patterns and the development of plantar keratotic lesions. Pressure from footwear may also lead to the formation of an adventitious bursa over the joint, which may become inflamed (Fig. 8.2).

The exact prevalence of hallux valgus is difficult to determine because of the paucity of large-scale epidemiological studies and varying definitions used in the literature. In people aged over 65 years of age, prevalence rates ranging from 5% to 37% have been reported. Women are significantly more likely to develop hallux valgus than men, with sex ratios as high as 9:1. The condition has a significant impact on balance and gait patterns and is an independent risk factor for falls. A recent study also demonstrated that people with hallux valgus exhibited significantly lower scores on a health-related quality of life questionnaire, suggesting that the condition has a much broader impact than local pain and discomfort.
Hallux valgus is generally deemed to be present when the angle formed by the bisection of the first metatarsal and the proximal phalanx (the hallux abductus angle) is greater than 15° and the angle formed by the bisection of the first metatarsal and second metatarsal (the intermetatarsal angle) is greater than 9°. Several classification systems have been proposed based on the degree of angular deformity and the severity of symptoms, primarily to assist in the selection of surgical procedures. Mann has proposed a simple grading system based on the hallux abductus and intermetatarsal angles, which has been widely adopted for presurgical planning (Table 8.1). The simplest clinical grading system is the Manchester scale, which consists of four standardised photos covering the spectrum of the deformity (Fig. 3.6). A recent study by Menz & Munteanu showed that gradings using this scale were significantly associated with hallux abductus and intermetatarsal angles obtained from foot radiographs. Although this scale does not provide any information regarding the degree of joint degeneration or sesamoid displacement, it is a very useful tool for documenting the overall severity of angular displacement of the hallux in clinical settings where radiographs are not readily available or are considered unnecessary.

**AETIOLOGY**

The aetiology of hallux valgus is not well understood. There is some evidence that the condition is an autosomal dominant trait with partial penetrance, as between 58% and 90% of people with hallux valgus report a familial tendency. Johnston documented 101 family members across seven generations and reported that all but two affected parents passed
the condition on to their children. More recently, Pique-Vidal et al.\textsuperscript{19} constructed pedigree charts from 350 patients across three generations and found that family history was positive in 90\% of cases, with vertical transmission affecting some families across all three generations. However, because congenital hallux valgus is extremely rare, it appears that some intrinsic structural or functional tendency is inherited that may take several decades to develop into hallux valgus.

Because of this prolonged timeframe, our understanding of potential risk factors is limited to case-control studies, which provide evidence of association but not causation. Indeed, many of the proposed risk factors for hallux valgus could plausibly be argued to be consequences of the condition rather than causes. The most commonly proposed aetiological factors for hallux valgus are footwear, metatarsus primus varus, long first metatarsal, metatarsal head shape, muscle dysfunction and foot pronation. Each of these factors is briefly outlined below; however, for a more comprehensive discussion, the reader is referred to Kilmarlin & Wallace.\textsuperscript{21}

**Footwear**

The suggestion that footwear may be a contributing factor to the development of hallux valgus is driven by three major observations reported in the literature: the very low prevalence of the condition in people who do not wear shoes,\textsuperscript{22–24} the increase in prevalence observed when footwear is introduced into previously non-shoewearing populations\textsuperscript{25–29} and the significantly higher prevalence of the condition in women, many of whom wear shoes with an elevated heel and narrow toebox.\textsuperscript{30} It is physiologically plausible that wearing narrow-fitting shoes may result in the foot adapting to the confined space within the shoe via lateral deviation of the hallux and that, over time, soft tissue contracture and bony remodelling may cause the foot to assume this new position. The contribution of heel elevation is less clear, as many shoes with an elevated heel also have a narrow toe box, making a delineation between the contribution of each feature difficult. However, there is evidence that heel elevation alters the kinematics of the first metatarsophalangeal joint\textsuperscript{31,32} and leads to a medial shift in weightbearing pressures during gait,\textsuperscript{33–36} factors that may contribute to the gradual lateral displacement of the hallux. While the contribution of footwear to the development of hallux valgus is unlikely to be adequately resolved, it is clear that the condition is more common among people who wear shoes and, at the very least, the wearing of ill-fitting shoes is likely to aggravate pre-existing hallux valgus, particularly in those with a very broad forefoot.\textsuperscript{3}

**Metatarsus primus varus**

Metatarsus primus varus (also referred to as metatarsus primus adductus) refers to excessive angulation of the first metatarsal relative to the second metatarsal, and is generally considered to be present when the intermetatarsal angle is greater than 14°.\textsuperscript{37} Metatarsus primus varus is an inherent anatomical variant caused by the oblique orientation of the first metatarsocuneiform joint, and is thought to predispose to hallux valgus as a result of the bowstringing of the flexor hallucis longus tendon pulling the proximal phalanx into an abducted position.\textsuperscript{38} However, while there is a strong correlation between metatarsus primus varus and hallux valgus,\textsuperscript{1} it has also been observed that, as the lateral deviation of the hallux increases with increasing severity of the condition, the intermetatarsal angle also increases.\textsuperscript{17} As such, it is also possible that metatarsus primus varus is a result, rather than a cause, of hallux valgus.

**Long first metatarsal**

An overly long first metatarsal as a potential cause of hallux valgus was first proposed by Hardy & Clapham,\textsuperscript{1} who reported that the first metatarsal was on average 4 mm longer than the second metatarsal in 91 patients with hallux valgus, compared to an average of 2 mm longer in 84 people without hallux valgus. Similar results were reported in two subsequent studies.\textsuperscript{39,40} The proposed mechanism for the relationship between long first metatarsal and hallux valgus is simply that the longer first ray segment is more likely to undergo compression from footwear and, because of the angulation of the first metatarsal relative to the second, the hallux is predisposed to deviate laterally towards the lesser toes.\textsuperscript{40} As it is unlikely that hallux valgus will lead to a lengthening of the first metatarsal, causality is perhaps more convincing for long first metatarsal than for other hypothesised intrinsic factors.

**Metatarsal head shape**

Two broad categories of the shape of the first metatarsal head were identified by Mann & Coughlin\textsuperscript{2} in 1981 – round and square. Theoretically, hallux valgus
would be more likely to occur in feet with a round first metatarsal head, as this articular configuration would facilitate the transverse plane rotation of the proximal phalanx. In contrast, a square first metatarsal head would act to resist transverse plane forces placed on the hallux from footwear. There is limited evidence to support metatarsal head shape as a contributing factor to hallux valgus. Indeed, a study of 50 children with hallux valgus found that 40 exhibited square metatarsal heads. Furthermore, establishing such a relationship in older people with hallux valgus would be difficult, as arthritic degeneration in long-standing hallux valgus results in marked changes to the architecture of the metatarsal head.

### Muscle dysfunction

Several authors have suggested that an imbalance between the abductor and adductor hallucis muscles, with the latter overpowering the former, may have the effect of pulling the proximal phalanx laterally, thereby initiating the development of hallux valgus. Electromyographic studies have confirmed that there is indeed a reduction in abductor hallucis muscle activity in people with hallux valgus; however, whether this occurs before or after the condition develops is unknown. Anomalous tendon insertions have also been proposed as a potential cause of hallux valgus; however, extensive cadaver studies by Brenner failed to find any differences in the insertion patterns of either tibialis anterior or abductor hallucis in feet with or without the condition.

### First ray hypermobility

Three case-control studies have provided evidence of the proposed relationship between hypermobility of the first ray and hallux valgus. Ito et al compared changes in the lateral talo-first metatarsal angle from non-weightbearing to weightbearing in 32 people with hallux valgus and 23 controls, and found that those with hallux valgus underwent a greater reduction in this angle when bearing weight (indicative of greater dorsiflexion of the first ray). Consistent with this finding, Glasoe et al reported that 14 people with hallux valgus exhibited greater dorsal mobility of the first ray compared to age- and sex-matched controls when a controlled dorsiflexory force of 55 Newtons was applied to the first metatarsal head. Finally, Lee & Young measured first ray dorsiflexion and metatarsal length 60 hallux valgus cases and 40 controls and reported that the hallux valgus group exhibited slightly greater dorsiflexory motion (12.9° versus 10.3°).

### Foot pronation

The proposed association between pronated/flat feet and hallux valgus dates back as far as 1893 but, despite several authors noting that the condition seems to be more common in people with flat feet, there have been few case-control studies conducted to adequately address this relationship. The theory espoused by Root et al, widely adopted by the podiatry profession, suggests that subtalar joint pronation renders the forefoot hypermobile, thereby allowing ground reaction forces to dorsiflex and invert the first metatarsal, which then results in erosion of the inter-sesamoidal ridge by the tibial sesamoid and subsequent lateral displacement of the proximal phalanx. Evidence to support this assertion is scarce. Indeed, two studies comparing foot posture measurements between children with and without hallux valgus have failed to find any significant differences between the two groups. In contrast, Kernozek et al recently reported that 40 patients with hallux valgus had a significantly more everted calcaneal stance position (indicative of greater foot pronation) compared to 51 controls. Because of significant variations in definitions of the flat or pronated foot, it is difficult to directly compare these findings. Furthermore, the relationship between static foot structure and dynamic function is, at best, only moderate, so until comparisons are made using kinematic models the relationship between foot function and hallux valgus will remain elusive.

### Other potential causes of hallux valgus

In addition to the proposed intrinsic risk factors described above, hallux valgus has been observed to develop secondary to several other systemic conditions, including a range of inflammatory joint diseases (e.g. rheumatoid arthritis, gout and psoriatic arthropathy), conditions associated with ligamentous laxity (e.g. Ehlers–Danlos syndrome, Marfan’s syndrome and Down’s syndrome), and neuromuscular disorders (e.g. cerebral palsy, poliomyelitis and Charcot–Marie–Tooth disease). Iatrogenic hallux valgus may also develop secondary to surgical removal of the tibial sesamoid.
ASSESSMENT AND DIAGNOSIS

Assessment and diagnosis of hallux valgus is relatively straightforward. Patients will typically present with an enlarged and painful first metatarsophalangeal joint, with symptoms exacerbated by weightbearing activity and the wearing of ill-fitting or high-heeled footwear. Physical examination will reveal lateral deviation of the hallux and, depending on the severity of the deformity, overcrowding of the lesser toes may have resulted in the development of hammer- or claw-toe deformities. In severe cases, the second toe may be subluxed at the metatarsophalangeal joint and over- or under-ride the deviated hallux. The medial prominence of the first metatarsophalangeal joint (the “bunion”) may appear inflamed, and in some cases a fluid-filled bursa may have formed over the enlarged dorsomedial aspect of the joint. The hallux nail may be dystrophic or involuted because of pressure from footwear, and the tendon of extensor hallucis longus may be prominent and laterally displaced because of the gradual weakening of the extensor hood. Changes in weightbearing patterns often give rise to the development of calluses or corns beneath the metatarsal heads, most commonly located under the second metatarsal head because of the hypermobility of the first ray.

Further examinations are generally not required to diagnose hallux valgus; however, weightbearing radiographs, particularly dorsoplantar views, enable accurate grading of the deformity and are essential for surgical planning. Several well-established measurements can be derived from a dorsoplantar radiograph: the hallux abductus angle, intermetatarsal angle and hallux interphalangeus abductus angle (Fig. 8.3). This view also provides useful insights into the degree of arthritic degeneration in the joint. Observational gait analysis may reveal reductions in walking speed and step length,11 and plantar pressure analysis will generally reveal a reduction in loading under the hallux and first metatarsal head but a corresponding increase in loading under the lateral metatarsal heads (Fig. 8.4).54,56

TREATMENT

Conservative

Conservative management of hallux valgus includes measures to obtain pain relief, addressing the associated nail and skin conditions, and the provision of interventions to realign (or at least slow the progres-
sion of) the deformity. All skin lesions and nail disorders should be managed as described in Chapters 3 and 5, with particular emphasis placed on ensuring that lesions are sufficiently palliated and that the contribution of ill-fitting footwear is appropriately addressed. Extra-depth and wider-fitting footwear may need to be prescribed and fitted, and soft moulded orthoses inserted to offload painful plantar regions. The application of foam or silicon gel pads to offload the medial prominence may also provide some degree of symptomatic improvement. 57

Several conservative techniques have been described to reduce the degree of hallux valgus and/or prevent further deformity, including toe splints 58–60 mobilisation and manipulation, 61 and foot orthoses. 62–64 However, a recent Cochrane systematic review found only two randomised controlled trials of conservative treatments involving adults. Juriansz 58 compared a hallux valgus night splint to no treatment in 28 people ranging in age from 10 to 77 years and found no difference in clinically determined degree of deformity. Torkki et al 64 compared the effectiveness of surgery, customised orthoses and no treatment in 211 patients and reported that orthoses significantly reduced pain after 6 months compared to no treatment, but this difference was not evident at 12 months. As no radiographs or clinical measurements were taken, it is unclear whether the degree of deformity was affected by treatment. In a randomised controlled trial that was not eligible for inclusion in the Cochrane review, Budiman-Mak et al 63 demonstrated that people with rheumatoid arthritis issued with foot orthoses were less likely to exhibit progression of the hallux abductus angle to the no-treatment control group after a 3-year follow-up period.

Since the publication of the Cochrane review, two additional conservative treatment studies have been published. Tang et al 59 conducted an uncontrolled study of an insole with a toe separator to realign the hallux in 17 patients aged 14–75 years, and reported an average 6.5° reduction in the hallux abductus angle and improvements in pain and walking ability at 3 months. More recently, Brantingham et al 61 conducted a randomised controlled trial comparing chiropractic manipulation and mobilisation (including longitudinal distraction and adduction of the hallux) to a sham treatment and reported significant improvements in pain threshold and Foot Function Index scores in the treatment group over a 3-week period.

Clearly, further research is required to thoroughly evaluate the efficacy of conservative treatments for hallux valgus. It is particularly important that such studies include older people, as the degree of arthritic degeneration associated with hallux valgus is likely to influence the likelihood of a successful outcome.

Surgical

Surgical intervention for hallux valgus is frequently indicated, as conservative management is generally only effective in alleviating symptoms and has little or no impact on the progression of the deformity or its secondary effects on mobility and quality of life. However, because hallux valgus is quite variable in its presentation, there is no ‘gold standard’ surgical procedure that can be applied to all patients. Rather, the condition needs to be viewed as a syndrome consisting of multiple pathologies, and careful presurgical planning is therefore recommended to achieve optimal outcomes. 65

When considering surgical intervention for hallux valgus, the potential adverse effects need to be carefully considered. Although it is difficult to predict the outcome in hallux valgus surgery, Rowley 66 has suggested that, in general, 70–80% of patients do well, 10–15% have a satisfactory outcome and 5–10% have an unsatisfactory outcome or are actually worse off following the procedure. However, the recent Cochrane review 67 of 18 randomised trials reported that up to one-third of patients were dissatisfied with their surgical result. Common complications associated with hallux valgus surgery include ongoing pain, transfer lesions (the development of lesions at previously lesion-free sites because of changes in foot function), joint stiffness, stress fractures, ‘floating hallux’ (loss of function of the hallux due to plantarflexion weakness) and irritation from internal fixation devices (K-wires and screws). 68,69 Two recent studies have also indicated that, while hallux valgus surgery reduces pain and improves quality of life, the appearance of the foot and the range of shoes that can be worn following the procedure are significant predictors of satisfaction with the surgical result. 70,71

Over 150 different procedures have been described for hallux valgus, involving bony or soft tissue correction, or a combination of both. 67 The simplest procedure is Silver’s bunionectomy, 72 which involves the removal of the medial eminence of bone without correcting the underlying angular deformity. More complex procedures may involve fusion of the first metatarsophalangeal joint, displacement of the first metatarsal,
plantarflexing or dorsiflexing the first ray, reducing the intermetatarsal angle by removing a wedge of bone from the base of the first metatarsal, and various tendon lengthening and shortening procedures. The following section briefly describes some of the more commonly performed techniques. For a more detailed coverage, the reader is referred to a recent comprehensive review by Kilmartin and to specialist foot surgery texts.

The technique now known as the Keller procedure was originally described in the German literature but was translated into English by Keller in 1904. This common and technically straightforward procedure involves removing the base of the proximal phalanx and medial eminence of the first metatarsal (Fig. 8.5). As no further correction of the angular deformity is undertaken, recurrence is common and it has therefore been suggested that this procedure is suited to older people who are not physically active.

The Akin procedure was described in 1925 and involves resection of the medial eminence followed by the removal of a wedge-shaped piece of bone from the base of the proximal phalanx (Fig. 8.6). In contemporary practice, this procedure is rarely undertaken as a stand-alone surgery but may be combined with other osteotomies. In addition to correcting the transverse plane alignment of the hallux, the osteotomy can be angled to provide correction in the frontal plane if required.

The scarf osteotomy was described in 1926 and is based on (and named after) a joint commonly used in carpentry. The technique involves making a longitudinal, Z-shaped step-cut osteotomy through the metatarsal. The metatarsal head and plantar cortical fragment are then translated laterally and fixed with two compression screws (Fig. 8.7). The scarf osteotomy is particularly useful for correcting large intermetatarsal angles and is comparatively stable; however, it is a technically demanding operation that requires considerable surgical expertise.

The Lapidus procedure was described in 1934. This technique involves removal of the medial prominence, followed by fusion of the metatarsocuneiform joint in conjunction with the insertion of bone chips taken from the medial eminence in the space between the first and second metatarsals. This procedure is considered to be particularly useful for surgical correction of hallux valgus with large intermetatarsal angles and/or arthritic degeneration of the metatar-
socuneiform joint; however, common complications associated with the technique include non-union, overcorrection leading to hallux varus, and development of secondary osteoarthritis in adjacent joints.69

The *Mitchell osteotomy*, described by Hawkins in 1945,77 involves removing a rectangular section of bone from the metatarsal neck and displacing the metatarsal head laterally and proximally (Fig. 8.8). The procedure invariably results in some shortening of the metatarsal, which may be responsible for the relatively common occurrence of transfer lesions in some patients. A long-term follow-up study of 95 patients (mean follow-up of 21 years) by Fokter et al78 indicated a very high (52%) recurrence rate associated with the procedure.

The *Wilson osteotomy* was developed in the 1950s79 and is similar to the Mitchell osteotomy; however, rather than removing a rectangular section of bone, an oblique osteotomy is made through the metatarsal neck, enabling the metatarsal head to be slid laterally and proximally (Fig. 8.9). As with the Mitchell procedure, transfer lesions and metatarsalgia are relatively common (up to 33%) because of metatarsal shortening.80

The *Chevron procedure* was first described in 197981 and has become one of the most commonly performed surgical techniques for adult hallux valgus. The procedure involves separating the metatarsal head from the metatarsal neck using a V-shaped osteotomy, sliding the metatarsal head laterally and inserting K-wires or screws to hold the metatarsal head in its new position (Fig. 8.10). The benefits of the technique are its technical simplicity and stability; however, avascular necrosis is relatively common as a result of severing the arterial supply to the metatarsal head.69 Furthermore, it has been suggested that the technique is inappropriate in cases where the intermetatarsal angle is greater than 15°.

*Basal osteotomies* involve making an osteotomy cut through the base of the first metatarsal and then levering the metatarsal laterally to ‘close’ the intermetatarsal angle.55 The two most common types are the *closing wedge osteotomy*, in which a wedge of bone is removed on the lateral aspect of the base of the first metatarsal, and the *crescentic osteotomy*, in which a proximally directed concave osteotomy is made 1 cm distal to the metatarsocuneiform joint and the metatarsal is rotated laterally (Fig. 8.11). Basal osteotomies
are indicated for the correction of large intermetatarsal angles; however, because the technique results in metatarsal shortening, transfer metatarsalgia is a common complication. 

Arthrodesis (fusion) of the first metatarsophalangeal joint following resection of cartilage from the metatarsal head and proximal phalanx is a destructive procedure that is generally reserved for hallux valgus with severe joint degeneration. Once fused, the hallux position cannot be altered, and for this reason the angle at which the fusion is performed is extremely important. Excessive dorsiflexion may lead to the development of calluses under the first metatarsal head, whereas inadequate dorsiflexion may result in arthritic degeneration of the interphalangeal joint of the hallux. For these reasons, arthrodesis is generally a ‘last resort’ and the decision to fuse the joint must be very carefully considered.

Despite the large number of surgical procedures that have been described for hallux valgus, few have been adequately examined or directly compared to other techniques. The most recent Cochrane review of treatments for hallux valgus identified only 18 studies in which patients had been randomly allocated to different interventions, and only one that used a no-treatment control group for comparison. Although one study demonstrated that patients undergoing a Chevron osteotomy had better outcomes than patients receiving foot orthoses, no surgical techniques were found to be superior to any other and the number of participants expressing dissatisfaction at follow-up was consistently high (25–33%). Furthermore, three trials comparing procedures as they were originally described to the surgeon’s modification of the technique reported no significant advantages for the modification. Clearly, there is considerable scope for future research into the relative merits of different surgical techniques for hallux valgus.

Hallux limitus and hallux rigidus

Hallux limitus is a condition in which there is a restriction in the range of motion of the first metatarsophalangeal joint. If this progresses to complete fusion of the joint, the term hallux rigidus is used, although the two terms are frequently used interchangeably. Rzonca et al argued that the term hallux equinus should be used to encompass the entire spectrum of the condition; however, this terminology has not been widely adopted. Other less commonly used terms related to the condition are dorsal bunion and hallux flexus, the former used when there is evidence of an osseous prominence on the dorsal aspect of the joint, and the latter when the resting position of the hallux is in flexion.

The condition was first described by Coterill in 1887 and was primarily considered to be an affliction of adolescents that developed in response to trauma (e.g. stubbing the toe) or ill-fitting footwear. Hallux limitus/rigidus is also considered to be common in older people; however, the precise epidemiology is very difficult to determine as the condition is rarely included in large-scale surveys. Furthermore, there is some overlap between hallux limitus/rigidus and osteoarthritis of the first metatarsophalangeal joint, which in one large-scale study was found to affect 44% of people over the age of 80 years. There is a general consensus that women are affected twice as commonly as men.
In addition to ‘structural’ hallux limitus/rigidus, an additional ‘functional’ form of the condition has been proposed. *Functional hallux limitus* describes a condition in which there is normal range of motion at the first metatarsophalangeal joint when measured non-weightbearing; however, there is a reduced range of dorsiflexion evident during the propulsive phase of gait. The initial cause of this limitation is unclear; however, several authors have suggested that functional hallux limitus is a precursor to structural hallux limitus/rigidus.

## Classification and Clinical Presentation

Several classification systems for hallux limitus/rigidus have been proposed, based on radiographic criteria alone, or a combination of radiographic and clinical features. However, few of these scales have been adequately validated and no direct comparisons between the scales have been undertaken. A summary of three of the most commonly reported scales (Regnauld, Hattrap & Johnson and Coughlin & Shurnas) is provided in Table 8.2. Perhaps the most useful grading system is that of Coughlin & Shurnas, which incorporates clinical and radiographic features and provides first metatarsophalangeal joint dorsiflexion ranges of motion commonly observed with each grade. This scale has also been shown to have prognostic value in determining the response to surgical intervention.

Patients with hallux limitus/rigidus typically present with complaints of pain and stiffness in their big toe joint that increases with activity and is alleviated by rest. Paraesthesia may be present because of compression of the dorsal digital nerve of the hallux. On examination, the first metatarsophalangeal joint may be swollen and erythematous and in long-standing cases there will be a dorsal exostosis overlying the first metatarsal head (Fig. 8.12). Secondary features include bursal formation, hyperextension of the interphalangeal joint with associated hallux nail dystrophy, and keratotic lesions, typically located under the medial aspect of the interphalangeal joint and lesser metatarsophalangeal joints. Gait analysis will reveal an apropulsive walking pattern with a shortened step length, possibly accompanied by excessive knee and hip flexion or hip circumduction to assist the transfer of the swing limb. Plantar pressures will generally be elevated beneath the hallux and lateral metatarsal heads (Fig. 8.13).

## Aetiology

The aetiology of hallux limitus/rigidus is considered to be multifactorial; however, few well designed studies have been undertaken. Most investigations have been case series designs, which simply report the prevalence of various features in patients with hallux limitus/rigidus with no comparison to a control group. These studies have suggested that hallux limitus/rigidus is associated with female sex, family history of the condition, long first metatarsal, increased hallux interphalangeal abductus angle and foot pronation.
<table>
<thead>
<tr>
<th>Grade</th>
<th>Regnould Radiographic</th>
<th>Hattrap &amp; Johnson Radiographic</th>
<th>Coughlin &amp; Shurnas Radiographic</th>
<th>Clinical</th>
<th>1st MPJ DF ROM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade 0</td>
<td>–</td>
<td>–</td>
<td>Normal</td>
<td>No pain</td>
<td>40–60° and/or</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Slight stiffness</td>
<td>10–20% loss</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Reduced ROM</td>
<td>compared to normal side</td>
</tr>
<tr>
<td>Grade 1</td>
<td>Condensation of bone around the joint</td>
<td>Mild to moderate osteophytes Normal joint space</td>
<td>Dorsal osteophyte Minimal joint space narrowing Minimal periarticular sclerosis Minimal flattening of metatarsal head</td>
<td>Mild/occasional pain and stiffness Pain at extremes of DF and/or PF</td>
<td>30–40° and/or 20–50% loss compared to normal side</td>
</tr>
<tr>
<td>Grade 2</td>
<td>Moderate osteophytes Joint space narrowing Subchondral sclerosis or cysts Hypertrophy and irregularity of sesamoids</td>
<td>Moderate osteophytes Joint space narrowing Subchondral sclerosis</td>
<td>Dorsal, lateral and possibly medial osteophytes Flattened appearance of metatarsal head No more than one-quarter of dorsal joint space involved on lateral radiograph Mild-moderate joint space narrowing and sclerosis Sesamoids not involved</td>
<td>Moderate to severe pain and stiffness that may be constant Pain occurs just before maximum DF and maximum PF</td>
<td>10–30° and/or 50–75% loss compared to normal side</td>
</tr>
<tr>
<td>Grade 3</td>
<td>Severe osteophytes Complete disappearance of joint space Degenerative hallux-metatarsal- sesamoid joint</td>
<td>Marked osteophytes Loss of joint space Subchondral cysts present or absent</td>
<td>As for Grade 2, but with substantial narrowing, possible periarticular cystic changes, more than one-quarter of dorsal joint space involved on lateral radiograph Sesamoids enlarged and/or cystic or irregular</td>
<td>Nearly constant pain and substantial stiffness at extremes of range of motion, but not at mid-range</td>
<td>≤10° and/or 75–100% loss compared with normal side Notable loss of PF</td>
</tr>
<tr>
<td>Grade 4</td>
<td>–</td>
<td>–</td>
<td>As for Grade 3</td>
<td>As for Grade 3 plus definite pain at mid-range of passive motion</td>
<td>As for Grade 3</td>
</tr>
</tbody>
</table>

1st MPJ DF ROM, first metatarsophalangeal joint dorsiflexion range of motion, measured passively; PF, plantarflexion.
Stronger evidence can be derived from case-control studies, as direct comparisons are made to a control group without the condition. Four such studies have been undertaken. Horton et al.\textsuperscript{104} compared radiographic measurements in 81 patients with hallux rigidus and 50 controls and found that, while measures of metatarsus primus elevatus (relative elevation of the first metatarsal compared to the second metatarsal) were similar between controls and cases with mild to moderate deformity, severe cases of hallux rigidus demonstrated slightly higher mean values. Similar results were reported by Roukis,\textsuperscript{105} who compared 100 cases of hallux rigidus to historical controls and found that metatarsus primus elevatus was more common in the case group. Zgonis et al.\textsuperscript{106} compared radiographic features in 51 hallux rigidus cases to 51 controls and reported that the first metatarsal was slightly shorter in the hallux rigidus group (65 mm compared to 68 mm). However, first metatarsal protrusion distance, which is a more functional indicator of the length of the first metatarsal as it takes into account transverse plane angulation, did not differ between the groups. Bryant et al.\textsuperscript{107} compared radiographic measurements in 30 people with hallux limitus and 30 controls and reported an increased hallux interphalangeus abductus angle in the hallux limitus group. Finally, a large retrospective cohort study of 1592 people aged over 40 years found that those with osteoarthritis of the first metatarsophalangeal joint were more likely to have pronated feet, defined as a frontal plane rearfoot angle of greater than 5°.\textsuperscript{108}

These findings indicate that intrinsic structural factors may play a role in the development of hallux limitus/rigidus. The underlying mechanical cause of the degeneration of the joint, however, is subject to considerable debate. It has been hypothesised that subtalar joint pronation leads to first ray hypermobility and that the subsequent dorsiflexion of the first metatarsal limits the dorsal excursion of the proximal phalanx, leading to a ‘jamming’ of the joint (Fig. 8.14).\textsuperscript{51} This process would theoretically be exacerbated in the presence of an overly long or elevated first metatarsal. However, while reduced static dorsiflexion of the first metatarsophalangeal joint has been shown to be associated with pronated foot posture\textsuperscript{109,110} and decreases as the rearfoot is progressively everted,\textsuperscript{111} the relationship between eversion of the rearfoot complex and maximum first metatarsophalangeal joint dorsiflexion during gait is only moderate.\textsuperscript{112}

Irrespective of the underlying intrinsic risk factors, the essential pathology of hallux limitus/rigidus is one of progressive arthritic degeneration of the first metatarsophalangeal joint, initiated by synovial hypertrrophy and subsequent cartilage destruction. Loss of cartilage results in exposure of subchondral bone, which then undergoes sclerotic changes and, in severe cases, formation of subchondral cysts.\textsuperscript{82}

Finally, hallux limitus/rigidus has also been reported in people with arthritic disorders such as rheumatoid arthritis, gout and psoriatic arthropathy.\textsuperscript{82} The underlying mechanism for the development of limited joint motion in these conditions is likely to be localised joint inflammation and subsequent cartilage degeneration. However, Clayton & Ries\textsuperscript{113} have also suggested that, in the rheumatoid foot, spasm of intrinsic musculature of the toes may occur in an attempt to unload painful lesser metatarsal heads, resulting in
soft tissue contracture of the first metatarsophalangeal joint.

ASSESSMENT AND DIAGNOSIS

Diagnosis of hallux limitus/rigidus is based on clinical signs and symptoms, joint range of motion measurement and radiographic appearance. As stated above, the classical presentation of hallux limitus/rigidus is pain and stiffness in the first metatarsophalangeal joint that increases with activity and is alleviated by rest. Physical examination will frequently reveal a dorsal exostosis overlying the joint with associated inflammation and, in severe cases, bursal formation.

Non-weightbearing examination of the first metatarsophalangeal joint (Fig. 8.15) will reveal a limited range of dorsiflexion with normal or slightly restricted plantarflexion. The normal non-weightbearing range of motion of the first metatarsophalangeal joint has been reported to be between 50° and 82°, however, several measurement techniques have been described, which may not be directly comparable.

Furthermore, these normal ranges may not be applicable to older people, because of normal age-related reductions in joint range of motion. Recently, Scott et al. showed that older people without foot problems had significantly less range of motion at the first metatarsophalangeal joint compared to younger controls (56° versus 82°, measured non-weightbearing), indicating that a cut-off value of approximately 50° is probably a useful rule of thumb when assessing older people. If the condition is unilateral, it may be useful to compare the range of motion between both feet and document the relative reduction in motion on the affected side.

Weightbearing dorsoplantar and lateral radiographs are extremely useful to determine the severity of hallux limitus/rigidus (Fig. 8.16). The most obvious features of the condition are joint space narrowing and juxta-articular sclerosis (best viewed from the dorsoplantar radiograph), and the formation of an osteophyte on the dorsal aspect of the first metatarsal head (best viewed from the lateral radiograph). As the condition progresses, the metatarsal head takes on a flattened appearance, the sesamoids may become enlarged, and periarticular cysts may develop. Oblique
radiographs are not essential to assess the severity of hallux limitus/rigidus; however, they may assist in determining the full extent of the dorsal osteophyte. Similarly, computed tomography scans are generally not required but may assist in determining the degree of degeneration on the plantar surface of the joint, which is otherwise difficult to visualise with radiographs.

**TREATMENT**

**Conservative**

Conservative management of hallux limitus/rigidus involves measures to obtain pain relief (including anti-inflammatory medications and intra-articular corticosteroid injection), addressing the associated nail and skin conditions, physical therapy to restore range of motion, orthotic therapy and footwear modifications. Although very few rigorous trials have been undertaken to assess the efficacy of these treatments for hallux limitus/rigidus, case series studies suggest that many patients benefit from conservative management. In a recent 14-year follow-up study of patients who chose not to have surgery, few reported that their condition had worsened and 75% would still choose not to have surgery if they had to make the decision again. A large proportion of these patients had changed their footwear to shoes with a more ample toebox, suggesting that selection of appropriate footwear may be a sufficient treatment in many people.

Similar findings were reported by Grady et al., who reviewed 772 cases of hallux limitus over a 7-year period and reported that 55% were successfully managed with conservative care alone. Of these, 84% were managed with foot orthoses, 10% with intra-articular corticosteroid injections and 6% with a change in footwear.

Intra-articular injection and manipulation may be beneficial in mild to moderate cases of hallux limitus/rigidus. Solan et al. described a case series of 31 patients with hallux rigidus who were given an injection of 40 mg of Depo-Medrone and 3 ml of 0.5% bupivacaine followed by manipulation of the joint under general anaesthesia. After a mean follow-up of 41 months, one-third of patients with mild (Karasick & Wapner grade 1) hallux rigidus required surgery, two-thirds of patients with moderate (grade 2) hallux rigidus required surgery, and all patients with advanced (grade 3) hallux rigidus required surgery. The authors concluded that manipulation and injection has a role to play in the management of hallux limitus/rigidus but appears to be more effective in less severe cases. More recently, a randomised controlled trial by Pons et al. indicated that intra-articular injection of sodium hyaluronate, a highly viscous glycosaminoglycan thought to influence cartilage metabolism, was more effective than corticosteroid injection in early hallux rigidus. However, after one year, nearly half the participants required surgical intervention, suggesting that the benefits of this approach may be short-term.

Mobilisation of the sesamoid apparatus and strengthening of hallux plantarflexors has also been shown to confer an additional benefit in the conservative management of hallux limitus. Shamus et al. conducted a small trial in which one group of patients was provided with whirlpool, therapeutic ultrasound, first metatarsophalangeal joint mobilisation, calf stretching, toe strengthening exercises, cold packs and electrical stimulation, and the second group was provided with each of these interventions in addition to distal gliding mobilisations of the sesamoids, hallux plantarflexor strengthening exercises and gait training. After 12 therapy sessions, the group who received the sesamoid mobilisations exhibited greater improvements in first metatarsophalangeal joint range of motion, toe flexor strength and pain levels.

Footwear modification and orthotic management of hallux limitus/rigidus are greatly influenced by the severity of the condition. In advanced cases with large osteophytes, pain generally occurs during the propulsive phase of gait when the proximal phalanx jams against the metatarsal head. In such cases, the goal of treatment is to restrict motion. This can be achieved by the prescription of shoes with a rigid shank; however, the resultant need for sagittal plane compensation at the knee and hip may create symptoms further up the kinetic chain. Alternatively, rocker sole footwear will enable propulsion to occur proximal to the metatarsophalangeal joints, provided the apex of the rocker is appropriately located. Prescription of rocker-soled footwear needs to be carefully considered in older people, as some patients may take considerable time to adjust to the footwear because of balance difficulties. For those with severe hallux limitus/rigidus who are not suitable for rocker-sole shoes, the placement of an insole with a raised bar under the first ray may achieve the same result.

For less severe forms of hallux limitus (including functional hallux limitus), orthoses may assist in facili-
tating sagittal plane motion of the first metatarsophalangeal joint by increasing the plantarflexion of the first ray. This may be achieved by removing orthotic material beneath the first ray segment (‘first ray cut-out’), elevating the lateral metatarsal heads (via valgus forefoot wedges or metatarsal domes) or placing a firm piece of material beneath the hallux.127 Despite the proposed relationship between foot pronation and limited motion at the first metatarsophalangeal joint, the effect of varus rearfoot wedges in the management of hallux limitus is unclear, with both increases128 and decreases129,130 in first metatarsophalangeal joint motion reported while wearing such orthoses.

Despite clinical reports of the efficacy of footwear modifications and foot orthoses for hallux limitus/ rigidus,122,131 no controlled trials have so far been performed. However, it is likely that such interventions would be more effective in less severe forms of the condition where there is still a reasonable amount of available motion at the joint.

**Surgical**

As with hallux valgus surgery, there have been a multitude of procedures described for the management of hallux limitus/rigidus but few have been adequately evaluated or directly compared to each other. The selection of procedure is heavily influenced by the severity of the condition, so preoperative grading is considered essential. In mild cases, the aim of the surgery is to remove osteophytes and preserve joint motion, whereas in advanced cases the aim is to block the residual motion that is causing the pain by fusing the joint. The following section provides a brief overview of some of the more commonly performed procedures for hallux limitus/rigidus; however, the reader should note that this coverage is by no means comprehensive and several modifications of these techniques have been described in the literature.

The simplest joint preservation procedure, referred to as **cheilectomy**, involves removal of the dorsal exostosis from the metatarsal head and proximal phalanx, and debridement of the degenerative articular cartilage on the dorsal aspect of the joint (Fig. 8.17).93 Up to 30% of the metatarsal head is removed. This procedure is most appropriate for mild cases of hallux limitus/rigidus and results in significant increases in the dorsiflexion range of motion at the first metatarsophalangeal joint.132 Several retrospective studies have reported high levels of patient satisfaction with the technique (72–90%), with the only consistent complication being recurrence of the dorsal osteophyte.93,132–136 Feltham et al137 have stated that the technique is particularly effective in people aged over 60 years who have extra-articular symptoms.

Several joint preservation osteotomy procedures have been proposed for the surgical management of hallux limitus/rigidus (Fig. 8.17). The **Bonney–Kessel osteotomy**,138 a dorsiflexory osteotomy at the base of the proximal phalanx, is generally only used in younger patients or those with minimal degenerative changes and is contraindicated in the presence of metatarsus primus elevatus. The **Watermann osteotomy** is a distal metatarsal osteotomy in which a dorsal wedge of bone is removed, resulting in a relative shortening of the first metatarsal.139 However, for both these procedures, only small-scale follow-up studies have been reported.139,140

The **Youngswick procedure**,141 a modification of the Chevron bunionectomy, involves a V-shaped osteotomy through the neck of the first metatarsal along with the removal of a rectangular piece of bone from the dorsal aspect of the metatarsal to enable the proximalplantar displacement of the metatarsal head. Only two studies have reported outcomes of this procedure – the original description of 10 cases141 and a 2-year follow-up of 17 cases by Bryant et al,142 who reported significant increases in first metatarsophalangeal joint dorsiflexion but no changes in plantar pressures beneath the hallux or first metatarsophalangeal joint.

In more severe cases, joint destructive procedures are more frequently used. The **Keller procedure**, which has already been described in the previous section on hallux valgus (Fig. 8.3), has also been used with some success for hallux limitus/rigidus. However, the Keller procedure is generally only indicated for people with limited mobility and/or severe hallux limitus, as the propulsive function of the hallux is impaired following the procedure.89 Furthermore, as with hallux valgus, the Keller procedure is associated with a relatively high rate of complications such as transfer lesions and/or metatarsalgia, malunion and interphalangeal joint osteoarthritis.143 Finally, **implant arthroplasty**, which involves resecting a proximal portion of the proximal phalanx, remodelling the metatarsal head and inserting a silicone144,145 or metallic146 joint replacement, has received considerable attention in the recent literature and appears to provide significant pain relief while keeping the joint mobile. Several studies have shown the technique to be useful in older patients.144,147
Silicone implants appear to have a higher failure rate than metallic implants and are more likely to dislodge and lead to foreign body reactions.\textsuperscript{146} Only three randomised controlled trials have been conducted to assess the efficacy of surgical procedures for hallux limitus/rigidus. The first evaluated the benefit of K-wire distraction when performing a Keller’s arthroplasty but found that this modification conferred no additional advantages over the standard surgical technique. In fact, there was some evidence that distraction resulted in an increase in osteoarthritic changes in the interphalangeal joint.\textsuperscript{148} The second trial compared Keller’s arthroplasty to arthrodesis in patients with hallux valgus or hallux rigidus and found that the procedures produced similar outcomes.\textsuperscript{149} Finally, a well-designed trial comparing arthrodesis to implant arthroplasty reported better outcomes in the arthrodesis group, due primarily to the high rate of loosening of the phalangeal component of the implant.\textsuperscript{150}

Overall, surgical treatment of hallux limitus/rigidus does appear to be effective provided that extensive presurgical planning is undertaken. However, as with surgery for hallux valgus, there is a need for direct comparisons between different techniques with larger samples sizes and longer periods of follow-up.

LESSER TOE DEFORMITIES

Deformities of the lesser toes are among the most common of all foot disorders, affecting between 24% and 60% of older people. The Feet First study of 784 Americans aged over 65 years found that 35% of the sample had hammer toes, 33% had mallet toes and 9% had claw toes. Women are more likely to develop lesser toe deformities than men, which has been attributed to the influence of footwear with a narrow toe-box. Older people with lesser toe deformities are more likely to develop keratotic lesions on the toes and plantar surface of the foot and have more difficulty performing balance and functional tasks requiring forward leaning.

CLASSIFICATION AND CLINICAL PRESENTATION

There are several different types of lesser toe deformities, which are classified according to the relative alignment of the metatarsophalangeal and interphalangeal joints in the sagittal plane (Table 8.3). A mallet toe is a fixed deformity in which the distal interphalangeal joint is plantarflexed. A hammer toe is a deformity in which the proximal interphalangeal joint is plantarflexed and the metatarsophalangeal joint may be hyperextended. A claw toe is a deformity in which the metatarsophalangeal joint is hyperextended and both the proximal and distal interphalangeal joints are plantarflexed. A retracted toe is a deformity in which the metatarsophalangeal joint is hyperextended that the apex of the toe is non-weight-bearing. The proximal and distal interphalangeal joints may be neutral or plantarflexed.

In the presence of hallux valgus, the second toe frequently develops a hammer toe deformity. In severe cases, the second toe may be forced dorsally or plantarly to accommodate the lateral displacement of the hallux. In this situation, the terms over-riding (or cross-}

<table>
<thead>
<tr>
<th>Classification</th>
<th>Appearance</th>
<th>MPJ</th>
<th>PIPJ</th>
<th>DIPJ</th>
<th>Typical lesion pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mallet toe</td>
<td>Neutral</td>
<td>Neutral</td>
<td>Plantarflexed</td>
<td>Apex of toe</td>
<td></td>
</tr>
<tr>
<td>Hammer toe</td>
<td>Neutral or hyperextended</td>
<td>Plantarflexed</td>
<td>Neutral, or extended</td>
<td>Dorsum of PIPJ Plantar MPJ</td>
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<tr>
<td>Claw toe</td>
<td>Hyperextended</td>
<td>Plantarflexed</td>
<td>Plantarflexed</td>
<td>Dorsum of PIPJ Dorsum of DIPJ Apex of toe Plantar MPJ</td>
<td></td>
</tr>
<tr>
<td>Retracted toe</td>
<td>Hyperextended</td>
<td>Neutral or plantarflexed</td>
<td>Neutral or plantarflexed</td>
<td>Apex of toe non-weightbearing</td>
<td>Dorsum of PIPJ Plantar MPJ</td>
</tr>
</tbody>
</table>

DIPJ, distal interphalangeal joint; MPJ, metatarsophalangeal joint; PIPJ, proximal interphalangeal joint.
over) or under-riding toe may be used to describe the alignment of the second toe. Because of the subsequent subluxation of the second metatarsophalangeal joint, the second toe may also be displaced in the transverse plane. Similar transverse plane displacement may accompany hammer or claw toe deformities of the third to fifth toes due to pressure from footwear, giving rise to adductovarus toe deformity. A range of lesser toe deformities is shown in Figure 8.18.

Lesser toe deformities may be further classified according to the available motion in the affected joints, using the terminology of flexible or rigid or, alternatively, reducible or non-reducible. This nomenclature is clinically useful, as treatment strategies will vary depending on the degree of correction that can be achieved.

Older people with lesser toe deformities will frequently present with complaints related to secondary lesions (such as corns, calluses or ulcers) associated with the toe deformity (see Table 8.3 for typical patterns of lesion location associated with each type of deformity). Toe deformities with a transverse plane component (particularly adductovarus of the fifth toe) are often associated with interdigital lesions or nail dystrophy due to compression against the adjacent toe. In severe cases with multiple toe involvement,
there may be evidence of a cautious gait pattern due to loss of the propulsive function of the toes.\textsuperscript{158,159}

**Aetiology**

The aetiology of lesser toe deformities has not been thoroughly investigated and the evidence for many proposed aetiological factors is derived largely from clinical observations rather than case-control studies. Factors considered to be associated with the development of lesser toe deformities include ill-fitting footwear,\textsuperscript{30,154,156} abnormal foot posture (both pes planus\textsuperscript{51} and pes cavus\textsuperscript{160}) and excessively long toes.\textsuperscript{161} The proposed association between ill-fitting footwear and lesser toe deformities was recently supported by Menz & Morris,\textsuperscript{30} who assessed footwear characteristics in 176 older people and found that those with lesser toe deformities were two to four times more likely to wear shoes substantially shorter than their foot. Over time, it is likely that the toes adapt to the limited area available in the toe box of the shoe via hyperextension of the metatarsophalangeal joints and plantarflexion of the proximal interphalangeal joint.\textsuperscript{156} Lesser toe deformities also frequently develop in conjunction with systemic conditions such as diabetes mellitus,\textsuperscript{162} rheumatoid arthritis\textsuperscript{163} and Charcot–Marie–Tooth disease\textsuperscript{164} and may also develop following cerebrovascular accident (stroke).\textsuperscript{165}

**Assessment and Diagnosis**

Lesser toe deformities can be easily diagnosed via visual observation and physical examination. The foot should be observed both non-weightbearing and weightbearing, and passive range of motion tests for each joint should be undertaken in order to ascertain the degree to which the deformity is reducible. Secondary lesions associated with the deformity should be carefully inspected and documented. Evaluation of footwear (described in Chapter 3) is essential to assist in determining the underlying cause of the deformity and the suitability of the shoe to accommodate toe splinting devices.\textsuperscript{166}

Radiographic assessment is not required to diagnose lesser toe deformity but is necessary for presurgical planning. Dorsoplantar projections will enable the accurate identification of excessively long metatarsals by documenting the metatarsal formula. Lateral projections may enable the visualisation of severe hammer and claw toes; however, in this view all toes are superimposed, which makes accurate measurement quite difficult.

Plantar pressure analysis may be useful to accurately identify high pressure areas on the toes and to assess the efficacy of off-loading techniques. Claissé et al\textsuperscript{167} and Slater et al\textsuperscript{168} have recently demonstrated that modern plantar pressure systems have sufficient spatial resolution to detect reductions in toe pressures associated with prefabricated and custom-moulded silicone toe orthoses in people with claw toes.

**Treatment**

**Conservative**

Conservative treatment of lesser toe deformities involves addressing the associated nail and skin conditions, footwear advice and/or modification, and orthodigital techniques. In cases where it is clear that ill-fitting footwear is the underlying cause (or an aggravating factor), the older person should be advised to purchase more appropriately fitting footwear with a broad and deep toe-box. If this is not possible for financial or other reasons, shoe stretching or balloon-patching may be an appropriate alternative. Orthodigital techniques can be very effective in redistributing load away from painful areas and may also play a role in the non-surgical correction of flexible toe deformities.\textsuperscript{169} Each of these interventions is discussed in more detail in Chapter 11. However, despite anecdotal reports of effectiveness, no controlled trials of these conservative techniques have so far been undertaken.

**Surgical**

As with deformities of the first toe, several surgical procedures and modifications have been developed for the management of lesser toe deformities. A brief summary is provided in the following section but for further information the reader is directed to a recent comprehensive review by Coughlin.\textsuperscript{157}

The selection of surgical procedure for the correction of lesser toe deformities is highly dependent on the available motion in the interphalangeal joints. Generally speaking, rigid deformities require arthroplasty, whereas flexible deformities can be corrected with soft tissue surgical techniques such as tendon lengthening and transfer.\textsuperscript{157} For the mallet toe, an elliptical incision is made over the distal interphalangeal joint and deepened through the joint capsule and extensor tendon. The collateral ligaments are severed and the distal portion of the intermediate phalanx is removed. If the deformity is severe, the flexor tendon
may also be severed. The toe is then stabilised with a K-wire and taped into the corrected position. The wire is removed after a period of 3 weeks. The surgical procedure is essentially the same for hammer toes (with the exception that the procedure is directed to the proximal interphalangeal joint) and for claw toes (with the exception that both the proximal and distal interphalangeal joints are corrected). Although some authors recommend that peg-in-hole arthrodesis also be performed, Coughlin suggests that arthrodesis may occur naturally and is not necessary for a successful result to be achieved. Case series studies indicate that patient satisfaction with these procedures is generally high. Dissatisfaction with the surgical result is most commonly due to residual stiffness of the toes, recurrent deformity, malalignment and difficulty with footwear.

Amputation of the second toe for the management of severe crossover or hammer toe deformity has been recommended in older people for whom the recovery period of corrective surgery may be too debilitating. Sundaram & Walsh performed seven cases of second toe amputation in people aged over 70 years and reported that all were satisfied with the outcome. Similar results were reported by Gallentine & DeOrio in 13 patients (aged 72–86 years) who had undergone second toe amputation for severe hammer toe. However, this procedure needs to be carefully considered, as the postoperative cosmetic appearance may be troubling for some people. Furthermore, the space created by the absence of the second toe may increase any pre-existing valgus deformity of the hallux. Indeed, of the 20 cases reported in these two studies, 10 demonstrated valgus drift of the hallux following the procedure.

Surgical management of flexible lesser toe deformities involves tendon lengthening and/or transfer techniques. For retracted toes, a dorsal incision is made over the proximal interphalangeal joint and a Z-plasty tendon lengthening procedure is performed on the extensor digitorum longus tendon. For flexible hammer and claw toes, a flexor digitorum longus transfer (also referred to as the Girdlestone–Taylor procedure) is commonly used. This involves detaching the flexor digitorum longus tendon from the base of the distal phalanx, splitting it longitudinally and transferring each segment around the proximal phalanx and sutureing it to the extensor hood. Patient satisfaction with this procedure has been reported to range from 54% to 90%. Few complications have been associated with the technique; however, patients should be advised that the ability to flex the toes is lost following the surgery.

Fifth toe deformities frequently have a transverse and frontal plane component, because of their susceptibility to pressure from footwear. For this reason, several different surgical techniques have been developed specifically for the fifth toe. Overriding fifth toes can be managed with soft tissue release or, in more advanced cases, transfer of the extensor digitorum longus tendon. This procedure, first described by Lapidus, involves releasing the tendon 4 cm proximal to the metatarsophalangeal joint, then threading the distal portion around the proximal phalanx to the lateral plantar aspect of the toe. Here, the tendon is sutured to the tendon of abductor digitii minimi. An alternative procedure is to remove the proximal phalanx and syndactylise the fourth and fifth toes. Both procedures have reportedly high success rates, with recurrence of the deformity estimated to occur in less than 10% of cases. Syndactylisation, however, may not be cosmetically acceptable for some patients. Underriding fifth toes are less common but can be corrected by extensor digitorum longus tendon release and excision of the proximal phalanx.

LESS COMMON DISORDERS AFFECTING THE TOES

TAILOR’S BUNION

Tailor’s bunion, also referred to as bunionette, is an enlargement of the lateral aspect of the fifth metatarsal head (Fig. 8.19). The condition was originally...
observed in tailors and was thought to be caused by long periods sitting cross-legged with the lateral border of the foot compressed against the floor. As with hallux valgus, longstanding cases may develop a large, painful osseous prominence associated with an overlying adventitious bursa. Few epidemiological studies have documented the presence of tailor’s bunions, however, the Feet First study, which involved 784 people aged over 65, reported a 13% prevalence of ‘bunionette’, with equal distribution across men and women. Postulated aetiological factors for tailor’s bunion include incomplete development of the transverse intermetatarsal ligament, increased intermetatarsal angles associated with a broad forefoot, and congenital dumbbell-shaped fifth metatarsal head. However, no detailed case-control studies have been undertaken. Conservative treatment of tailor’s bunion involves addressing secondary skin lesions, advising the patient to purchase broader footwear, and the use of felt or silicone padding techniques to redistribute pressure away from the lateral eminence. Surgical management ranges from simple exostectomy to the use of distal osteotomies similar to those used for hallux valgus.

**HALLUX VARUS**

*Hallux varus* is an uncommon condition in which the hallux is adducted relative to the first metatarsal (Fig. 8.20). Although congenital forms of the condition do occur in conjunction with teratogenic anomalies, the most commonly encountered cause of hallux varus in older people is surgical overcorrection of hallux valgus deformity. Initial reports of iatrogenic hallux varus were attributed to surgical techniques advocating excision of the lateral sesamoid; however, it is now recognised that most hallux valgus procedures can potentially lead to hallux varus. Because of the increased breadth of the forefoot, patients will have great difficulty finding suitable footwear and are likely to develop keratotic lesions on the medial aspect of the hallux. Conservative treatments, such as splinting and strapping techniques, are generally of little use, so most cases will require revisional surgery. Several techniques have been described, which are essentially mirror images of hallux valgus procedures.

**GOUTY ARTHRITIS**

Gout is the most common inflammatory arthritis in older people, affecting approximately 3% of people aged over 65 years, with men being affected two to six times more frequently than women. Risk factors for the development of gout include alcohol consumption (particularly beer), renal insufficiency, diuretic use, dehydration, increased body mass index and dietary factors (including increased meat and seafood consumption, and decreased dairy consumption). The underlying pathophysiology of gout relates primarily to elevated blood levels of urate, a byproduct of purine metabolism. Normally, serum urate levels are between 2 and 8 mg/100 ml. However, in the presence of either overproduction of urate or, more commonly, impaired secretion of urate, monosodium urate crystals form and are deposited in the peripheral joints, resulting in acute inflammatory arthritis.

Acute gout initially affects the first metatarsophalangeal joint in 50% of cases and approximately 90% of patients will develop this manifestation at some point during the disease. The reason for this predilection is unclear; however, it has been hypothesised that the first metatarsophalangeal joint has a relatively low temperature, low pH and is subject to large compressive forces when walking; factors that may accelerate the
formation of monosodium urate crystals. Acute gout affecting the first metatarsophalangeal joint, often referred to as *podagra*, has a sudden onset and is exquisitely painful, and may last from a few days to several weeks. Other joints that are commonly affected by acute gout include the metatarsophalangeal joints, the ankle and the knee. If left untreated, approximately 75% of patients will develop chronic tophaceous gout, characterised by the formation of solid urate deposits (called *tophi*) in the connective tissues, most commonly the feet, fingers, elbows and ears (Fig. 8.21). Older women are more likely to develop tophaceous gout early in the disease process, possibly because of their higher prevalence of diuretic use.

Diagnosis of gout is confirmed by the microscopic observation of urate crystals in synovial fluid, bursae or tophi; however, clinical criteria are sufficient to reach a provisional diagnosis. These criteria include unilateral synovitis of the first metatarsophalangeal joint with maximum inflammation within 24 hours, no evidence of infection, a history of recurrent episodes of monoarticular arthritis followed by complete resolution, observation of subcortical bone cysts from radiographs, and rapid resolution of inflammation following administration of colchicine. Differential diagnoses include osteoarthritis, rheumatoid arthritis and septic arthritis. *Pseudogout*, a condition caused by deposition of calcium pyrophosphate crystals within joints, has a similar clinical presentation to gout but most commonly affects the knee, wrist or shoulder. Accurate differentiation between gout and pseudogout requires microscopic examination of synovial fluid.

Treatment of acute gout involves administration of colchicine (a potent anti-inflammatory drug), non-steroidal anti-inflammatory drugs (NSAIDs) or corticosteroid (either orally or via intra-articular injection). A recent systematic review indicated that, while colchicine is effective, high levels of gastrointestinal toxicity associated with the drug limit its use in older patients and, therefore, NSAIDs or corticosteroids should be the first line of treatment. Management of chronic gout involves counselling the patient with regard to weight loss, alcohol consumption and diet, and adjusting medications that contribute to hyperuricaemia. Allopurinol, a xanthine oxidase inhibitor, has been shown to significantly reduce urate levels and is therefore considered to be an effective drug for preventing recurrent gout. Prominences caused by tophaceous deposits will also need to be managed with footwear modifications and/or orthoses.

**SUMMARY**

An overview of the most common toe deformities affecting the older foot has been presented. Conservative management plays an important role in reducing the pain associated with secondary lesions caused by these deformities, and in some cases soft tissue correction may be possible with orthodigital techniques. Many older patients, however, will require surgical correction in order to remain pain-free. Because of the wide range of surgical options available for the correction of toe deformities, thorough presurgical planning is required to achieve optimum results.
31. Sussman RE, D’Amico JC. The influence of the height of the heel on the first metatarsophalangeal joint reaction forces during


96. Vanore JV, Christensen JC, Kravitz SR et al. Diagnosis and treatment of first metatarsophalangeal


Disorders of the forefoot

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DEFINITION, PREVALENCE AND CLASSIFICATION

The term metatarsalgia literally means pain in the metatarsal region of the foot and thus describes a symptom rather than a specific clinical entity. Establishing the prevalence of metatarsalgia is therefore very difficult. While prevalence rates of up to 65% have been reported for conditions of pain in the forefoot (such as plantar calluses, hallux valgus and hallux limitus/rigidus), this is likely to be an overestimate of the prevalence of metatarsalgia, as these conditions are not always symptomatic. Unfortunately, few studies have directly addressed the prevalence of site-specific foot pain. The Feet First study of 784 Americans aged over 65 years reported that 20% of the sample exhibited tenderness to palpation in the metatarsal head region, with equal sex distribution. More recently, Menz et al reported that 36% of 301 people aged over 75 years had disabling foot pain and of these 70% reported pain in the forefoot, which equates to a similar prevalence of forefoot pain (approximately 25%).

Several authors have attempted to classify metatarsalgia according to the underlying causes. Thomas et al proposed three types: primary metatarsalgia (caused by plantar keratoses, hallux valgus and hallux limitus/rigidus), secondary metatarsalgia (pain in the forefoot due to systemic disease) and metatarsalgia unrelated to weight distribution (including tarsal tunnel syndrome and vascular disease). Regnauld proposed four categories: diffuse metatarsalgia (caused by acquired mechanical/overuse disorders), localised metatarsalgia (caused by excessively long or
large metatarsals), subcutaneous soft tissue metatarsalgia (caused by intermetatarsal neuroma, bursitis and cysts) and cutaneous metatarsalgia (caused by plantar keratoses, verrucae or ulcers). Scranton\(^7\) proposed three categories: primary metatarsalgia (caused by hallux valgus, hallux limitus/rigidus or long first metatarsal), secondary metatarsalgia (caused by systemic conditions such as rheumatoid arthritis and gout, in addition to ‘local’ disorders such as stress fractures and sesamoiditis) and pain under the forefoot (caused by intermetatarsal neuroma, verrucae or tarsal tunnel syndrome). Finally, Dockery\(^8\) proposed three categories: primary metatarsalgia (including conditions related to abnormal anatomy of the metatarsals), secondary metatarsalgia (such as Morton’s neuroma, tarsal tunnel syndrome and forefoot pain secondary to systemic conditions) and iatrogenic metatarsalgia (most commonly as a result of osteotomy procedures).

Classification of metatarsalgia is clearly problematic and it is questionable whether such categorisation provides any clinical benefits or assists in diagnosis. However, what is clear from these classification systems is that pain in the forefoot may result from a myriad of causes, from localised skin, soft tissue or osseous pathology through to systemic conditions manifesting in the foot. Risk factors for the development of metatarsalgia therefore depend on the underlying condition that may be giving rise to forefoot symptoms. Nevertheless, Waldecker\(^9,10\) has recently conducted two case-control studies of unspecified metatarsalgia, based on the premise that anatomical and mechanical factors may be responsible for diffuse forefoot pain in the absence of other observable disorders. The first study revealed no difference in ultrasonically measured plantar fat pad thickness between cases and controls;\(^9\) however, the second study indicated that participants with hallux valgus and forefoot symptoms demonstrated increased plantar loading of the lateral metatarsal heads during gait.\(^10\) Over time, increased vertical loading may cause damage to plantar soft tissues, and there is also some evidence that increased plantar pressures may lead to a corresponding increase in pressure in the intermetatarsal spaces.\(^11\) Hsu et al\(^12\) and Wang et al\(^13\) have demonstrated that plantar soft tissues in older people demonstrate greater stiffness and dissipate more energy when compressed; however, the relationship between these changes and the development of symptoms has not yet been confirmed.

Ultrasound imaging has shed further light on the possible causes of forefoot pain. A study of 112 people with metatarsalgia and 50 controls revealed that the most commonly observed finding in those with metatarsalgia was intermetatarsal bursitis (21%), followed by intermetatarsal neuroma (15%) and effusion of the metatarsophalangeal joints (12%).\(^14\)

### DIAGNOSIS

Because of the large number of conditions that may result in forefoot pain, diagnosing the underlying cause can be challenging, particularly when multiple causes may coexist. A simple clinical algorithm involving a process of elimination, based on a system described by Coughlin,\(^15\) is shown in Table 9.1. The first step is to ascertain whether the pain is associated with a plantar keratotic lesion or verruca over the symptomatic site. Once this simple cause has been ruled out, systemic conditions that commonly result in forefoot pain, such as rheumatoid arthritis, osteoarthritis or gout, need to be considered, as joint degeneration or effusions associated with these conditions can lead to forefoot symptoms (Table 9.2).

Having ruled out a systemic cause, further detail regarding the nature of the symptoms should be sought, as neuritic symptoms (such as tingling, pins and needles, and referred pain into the toes) may indicate an intermetatarsal neuroma. This provisional diagnosis can be further explored using Mulder’s click test and ultrasound imaging (this is discussed later in the chapter). In the absence of neuritic symptoms, predislocation syndrome or insufficiency fractures of the metatarsals may need to be considered. Although the nature of the pain associated with predislocation syndrome can sometimes be vague, pain on plantarflexion and the tendency of the proximal phalanx to sublux when dorsal translation is applied are characteristic signs. Pain resulting from insufficiency fractures can be difficult to delineate from predislocation syndrome, so a definitive diagnosis may require bone scanning.

This simple algorithm will assist in the diagnosis of the most common causes of forefoot pain in older people; however, it needs to be kept in mind that a strict process of elimination is not always possible, as several conditions may coexist. Furthermore, if all these common diagnoses are ruled out, more extensive diagnostic imaging, including magnetic resonance imaging, may be required to diagnose less commonly encountered causes of forefoot pain, such as various soft tissue and bony tumours, infection and foreign bodies.
The most common cause of forefoot pain in older people is the presence of plantar keratotic lesions, which are discussed in detail in Chapter 4. Other commonly observed conditions in older people are intermetatarsal neuroma and predislocation syndrome. Insufficiency stress fractures of the metatarsals are only occasionally cited as a cause of forefoot pain in older people; however, they are likely to be more prevalent than is commonly recognised, because of misdiagnosis. Other conditions associated with forefoot pain, such as Freiberg’s infraction and sesamoid-
disorders of the forefoot

itis, are most commonly diagnosed in younger people and are therefore not discussed in this chapter.

## Intermetatarsal Neuroma

### Aetiology and clinical presentation

Intermetatarsal neuroma, also referred to as plantar digital neuroma, was first described by Lewis Dur- lacher in 1845 but is frequently attributed to Dudley Morton, who reported 11 cases in 1876. Consequently, the condition is also referred to as Morton’s neuroma or Morton’s metatarsalgia. The classical presentation is that of severe, neuritic pain in the third or fourth intermetatarsal space that radiates towards the toes, exacerbated by long periods of weightbearing and alleviated by rest or removal of footwear. Factors thought to be associated with intermetatarsal neuroma include female sex, increased body mass index, reduced space between the metatarsals, excessive foot pronation, elevated plantar pressures and the wearing of tightly fitting shoes; however, none of these proposed risk factors has been confirmed by case-control studies. Indeed, a recent case-control study by Betts et al found no difference in ultrasonically-measured intermetatarsal space or plantar pressures in 242 patients with neuroma symptoms compared to 35 controls.

The pathology of intermetatarsal neuroma is still uncertain but is thought to consist of neural fibrosis, oedema, demyelination and degeneration of the intermetatarsal nerve. However, histological comparison studies by Morscher et al and Bourke et al found no significant differences between cases and controls, with the exception of a higher proportion of cases exhibiting demyelination. Similarly, a magnetic resonance imaging study recently reported that, while slightly larger nerve lesions were observed in people with symptoms of intermetatarsal neuroma, there was a significant overlap between cases and controls. These findings suggest that degenerative changes in intermetatarsal nerves may be more common than previously thought and are not necessarily associated with neuroma symptoms.

The diagnosis of intermetatarsal neuroma is based on a combination of presenting symptoms, physical examination and diagnostic imaging. Compression of the affected intermetatarsal space may reproduce the symptoms and cause a palpable ‘click’ as the neuroma is subluxed beneath the transverse metatarsal ligament (referred to as Mulder’s click test; Fig. 9.1). However, this test is not highly specific, particularly in milder forms of the condition with less pronounced hypertrophy of the nerve. Ultrasound imaging is considered to be the most appropriate diagnostic modality, with sensitivities and specificities of between 85% and 100% when compared to intraoperative findings or postsurgical histopathology. Under ultrasound imaging, neuromas appear as elliptical hypoechogenic structures running parallel to the metatarsals that are integrated with surrounding nerve tissue. A transverse plantar scan is considered to be more accurate than a dorsal approach because of improved coupling; however, a dorsal scan is sometimes necessary when the plantar scan is negative. Although not as widely accessible, magnetic resonance imaging has also been used for the diagnosis of intermetatarsal neuroma, with similar sensitivity and specificity to ultrasound.
Conservative treatment

Conservative treatment of intermetatarsal neuroma involves changing footwear to shoes with a lower heel and broader forefoot, pressure redistribution using plantar padding techniques,19 foot orthoses34 and intralesional injections of cortisone35,36 or sclerosing agents.37–39 Retrospective studies suggest that, overall, conservative management is effective in at least 50% of cases.15,40 The most effective form of padding appears to be the plantar metatarsal pad (also called a metatarsal dome), placed proximally to the second to fourth metatarsal heads (Fig. 9.2A). This pad is thought to achieve pain relief by slightly elevating and spreading the central metatarsals, thereby increasing the intermetatarsal space and decreasing pressure on the neuroma itself.41 Plantar pressure studies have confirmed that this style of pad significantly reduces forefoot pressures42,43 and is more effective than apertured pads.43 Hirschberg44 has also claimed clinical success using a technique in which the fourth and fifth metatarsal heads are elevated by gluing a small lift under the insole of the shoe (Fig. 9.2B).

Intralesional injection of corticosteroid has quite variable success rates in the literature. While Greenfield et al35 reported that 80% of patients reported at least partial relief of symptoms following corticosteroid injection, a retrospective study of 115 patients by Bennett et al40 reported a much lower success rate (47%). Rasmussen et al36 found that while 80% of 43 patients who received a single corticosteroid injection obtained short-term symptomatic relief, at the 4-year follow-up period, approximately half were still symptomatic or had selected to undergo surgery. Repeated corticosteroid injection for intermetatarsal neuroma has been also associated with adverse reactions such as plantar fat pad atrophy44,45 and skin hyperpigmentation.45 It would therefore appear that corticosteroid injection may be useful temporary measure but cannot be considered an effective long-term strategy for the treatment of intermetatarsal neuroma.

Intralesional injection of sclerosing agent has been recommended by several authors. An uncontrolled study of 100 patients by Dockery reported an 89% success rate with three to seven injections of a 1 ml 4% alcohol solution every 5–10 days, with 82% reporting complete resolution of symptoms.37 Fanucci et al38 reported that ultrasound-guided injection of an anaesthetic and ethyl alcohol preparation achieved total or partial symptomatic relief in 40 patients after 10 months of follow-up. More recently, Hyer et al39 reported that, after 1 year of follow-up, five out of six patients achieved significant pain relief with a weekly series of three to nine injections of a 1 ml 4% alcohol solution.

Although these results are promising, larger studies with a control group are required to confirm the efficacy of conservative treatments. Indeed, the recent Cochrane review of interventions for intermetatarsal neuroma18 found only one controlled trial of conservative treatment—a study of 23 people who received either a supinatory or pronatory orthosis (manufactured from compressed felt) which reported no differences in reported pain levels between the two groups.46 Clearly, there is a need for more rigorous evaluation of both orthotic therapy and injection therapy in the treatment of intermetatarsal neuroma.

Surgical treatment

Surgical removal of intermetatarsal neuroma can be conducted under general, regional or even local anaesthesia and involves the resection of the affected nerve through a plantar, dorsal or web space incision. The most commonly used approach is through the dorsum of the foot, as this allows for earlier postoperative ambulation and does not result in plantar scarring.47 The efficacy of neuroma surgery has not been thoroughly evaluated; however, case series studies indicate that up to 24% of patients have unsatisfactory results.48–50 Adverse effects of neuroma surgery are
relatively common, including haematoma formation in the intermetatarsal space, ischaemia of the toes due to postoperative oedema and, the most troublesome complication, formation of a stump neuroma with symptomatic recurrence that often requires revisional surgery. Surgery appears to be more successful when only one neuroma requires excision.

The Cochrane review of treatments for intermetatarsal neuroma found only two randomised trials of surgical intervention. The first, a comparison of plantar and dorsal incision techniques, found that the efficacy of the techniques was similar; however, the dorsal approach resulted in less symptomatic postoperative scarring. The second study compared neuroma resection versus a technique in which the interdigital nerve is transposed into the intermuscular space between the adductor hallucis and interossei muscles. Patients who had undergone the intermuscular transposition technique were more likely to achieve at least 50% relief of pain compared to those who had the neuroma resected. The review, however, concluded that there is currently insufficient evidence upon which to adequately assess the efficacy of surgical treatments for intermetatarsal neuroma.

## PREDISLOCATION SYNDROME

### Aetiology and clinical presentation

Forefoot pain associated with instability of the metatarsophalangeal joints is a common clinical finding that has been described under several different titles in the podiatric and orthopaedic literature, including metatarsophalangeal joint instability, monoarticular non-traumatic synovitis, metatarsophalangeal joint subluxation, plantar plate rupture and, most recently, predislocation syndrome. Because the features of each of these conditions overlap and no diagnostic criteria have yet been developed, the term predislocation syndrome is probably the most appropriate terminology. The syndrome is characterised by a progressive, dorsal subluxation of the proximal phalanx on the metatarsal head that is thought to occur in response to a gradual weakening, inflammation and eventual rupture of the plantar plate. The second metatarsophalangeal joint is considered to be the most common site, although any of the lesser metatarsophalangeal joints may be affected. Although no case-control studies have been undertaken, case series studies and clinical observations suggest that the syndrome is associated with hallux valgus and the wearing of high-heeled footwear. However, Yu et al suggest that the absence of these factors does not necessarily preclude a diagnosis.

The classical presentation of predislocation syndrome is that of a focal, ‘bruise-like’ or throbbing pain on the plantar aspect of the joint that is exacerbated by long periods of weightbearing activity. No plantar keratotic lesions are generally present, although there may be some swelling evident and an associated widening of the interspace (Fig. 9.3). Significant transverse plane deviation of the toe occasionally occurs in advanced cases, which may indicate concur-

**Figure 9.3A, B** Early stage predislocation syndrome/plantar plate rupture. Note the dorsiflexion and displacement of the second toe, with corresponding increase in second interspace. (Courtesy of Matthew Dilnot, Melbourne Foot Clinic.)
rent rupture of the collateral ligament (Fig. 9.4). Direct palpation just distal to the metatarsal head will elicit symptoms, as will plantarflexion of the joint to end range of motion. Thompson & Hamilton have also described a clinical test in which the metatarsal head is stabilised with the thumb and index finger and a vertical, translational thrust is applied to the proximal phalanx with the contralateral hand (Fig. 9.5). The test result is then used to classify the severity of the condition using the following scoring system: 0 (no dorsal translocation occurs), 1 (the phalanx subluxes dorsally), 2 (the phalanx can be dislocated from the metatarsal head but manually reduced) and 3 (the phalanx lies in a fixed dislocated position).

Predislocation syndrome can be differentiated from other causes of metatarsalgia by the absence of keratotic lesions, neuritic symptoms or significant plain film X-ray findings. Bone scans may show increased localised uptake in the affected metatarsal head, while plantar plate rupture and synovitis of the flexor tendon sheath are readily observable with magnetic resonance imaging.

**Conservative treatment**

Conservative management of predislocation syndrome involves pain relief (using corticosteroids or non-steroidal anti-inflammatory medications), redistribution of pressure away from the affected site, and taping and splinting techniques to prevent further progression. Felt or foam padding placed under the affected metatarsal head will assist in elevating it relative to the proximal phalanx, which may reduce tension on the plantar plate. Crossover taping, in which the proximal phalanx is translated plantarly (Fig. 9.6), may achieve the same effect, although the need to frequently remove and reapply the tape makes it an impractical long term strategy.

Few studies have been undertaken to assess the efficacy of conservative management of predislocation syndrome. Mizel & Michelson reported a 70% success rate with intra-articular corticosteroid injection and prescription of rigid shank footwear. Similarly, Trepman & Yeo reported a 60% rate with steroid injection and the prescription of rocker sole shoes. In contrast to these two studies, Mann & Mizel reported that only one of seven patients with
metatarsophalangeal joint synovitis responded to anti-inflammatory medications and extra-depth shoes, with the remainder eventually requiring surgery. Variation in the severity of the condition may explain these disparate findings; however, controlled trials are required to adequately determine the efficacy of these approaches.

**Surgical treatment**

Surgical management of predislocation syndrome involves restoring normal plantar plate function by the release of soft tissue contractures, tendon transfer and lesser metatarsal osteotomy. These procedures are essentially modifications of techniques used to correct lesser toe deformities and are more fully discussed in Chapter 7. Combined soft tissue and osseous techniques have been recommended by Daly & Johnson, who described a technique involving partial proximal phalanx excision and syndactyly of the toes, and Yu and colleagues, who advocated extensor hood and joint capsule release, arthrodesis of the proximal interphalangeal joint, and transfer of the flexor digitorum longus tendon by threading it dorsally through a drill hole in the metatarsal head and securing to the dorsal periosteum. Although no large-scale, controlled studies have been undertaken, factors thought to be associated with metatarsal insufficiency fractures include overly long or short metatarsals, lateral metatarsal overload associated with hallux valgus, and the wearing of high-heeled shoes. Insufficiency fractures should also be suspected in older people presenting with transfer metatarsalgia following foot surgery, as several cases following Keller’s bunionectomy have been reported.

Dorsoplantar plain film X-rays may reveal a small transverse crack accompanied by subchondral sclerosis of the metatarsal head; however, this can be easily missed and may not be visible for 2–3 weeks after the onset of symptoms. Bone scans are substantially more sensitive and will reveal increased uptake in the metatarsal head as early as 3 days after symptoms develop.

**Treatment**

Treatment of insufficiency fractures involves offloading the affected site until the bone has sufficient time to heal. This may involve bed rest, use of crutches, various padding techniques to offload the metatarsal head, non-forefoot-loading surgical boots or below knee plaster casts. Complete healing generally takes 6–8 weeks. Optimising the management of pre-existing conditions that may result in osteopenia (such as osteoporosis, hyperparathyroidism and rheumatoid arthritis) is an important component of insufficiency fracture treatment. Furthermore, older patients diagnosed with insufficiency fractures without a history of osteoporosis should also be referred for bone density assessment.

**SUMMARY**

Forefoot pain is common in older people and may result from a combination of local and systemic conditions. The non-specific term metatarsalgia should not be considered an adequate diagnosis, as there are few
clearly identifiable factors that are consistently found in patients with forefoot symptoms. Instead, older people who report pain in the forefoot region should undergo a structured, step-wise diagnostic work-up to ascertain the most likely skin, soft tissue or osseous pathology responsible for the presenting symptoms. Because of the relatively high rate of complications and moderate levels of patient satisfaction associated with surgery, conservative management of forefoot pain should always be trialled first.

References

Disorders of the midfoot and rearfoot

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PLANTAR HEEL PAIN SYNDROME

Plantar heel pain is one of the most common conditions affecting the foot, accounting for over 1 000 000 patient visits to medical practitioners in the USA per year. Of these visits, 16% are made by people over the age of 65 years.1 The Feet First study of 784 Americans aged over 65 years reported that 4% exhibited tenderness to palpation of the plantar heel pad and 7% to palpation of the arch, with equal sex distribution.2 More recently, Menz et al3 reported that 16% of 301 people aged over 75 years had disabling foot pain affecting the heel. Plantar heel pain has also been shown to have a significant impact on mobility and health-related quality of life. Riddle et al4 administered the Lower Extremity Functional Scale to 50 participants with heel pain and reported that most experienced some difficulty in walking-related and occupational activities. In older people, the impact of the plantar heel pain is considerable. In a secondary analysis of the Feet First study, Badlissi et al5 found that older people with heel pain exhibited significantly lower scores on the Foot Health Status Questionnaire after accounting for age and comorbidities.

CLASSIFICATION AND CLINICAL PRESENTATION

The nomenclature and classification of heel pain is highly problematic. Heel pain has been variably referred to as plantar fasciitis, subcalcaneal bursitis, neuritis, subcalcaneal pain, stone bruise, calcaneal periostitis, heel spur syndrome, subcalcaneal spur and calcaneodynia.6–8 The most widely used term is plantar
fasciitis; however, recent evidence suggests that this may be a misnomer as no inflammatory cells are evident in postoperative histology specimens of the plantar fascia. Similarly, terms incorporating the word ‘spur’ are problematic as calcaneal spurs are commonly found in people without heel pain. Because the aetiology of heel pain is unclear (and is likely to be multifactorial) the term plantar heel pain syndrome is probably the most appropriate terminology to use until a definitive diagnosis is obtained using diagnostic imaging.

Several authors have proposed classification systems for heel pain, although none have been widely adopted. Shikoff et al proposed two categories of heel pain: local (including plantar fasciitis and plantar calcaneal bursitis) and systemic (including heel pain associated with connective tissue diseases and vascular disease). Kwong et al recommended a more complex classification system, including inflammatory, metabolic, degenerative, nerve entrapment, traumatic and overuse subgroups. Perhaps the most useful clinical classification is that proposed by Singh et al, which categorises inferior heel pain according to the tissue involved (Fig. 10.1). Although in practice there is likely to be some overlap between these categories, such a system provides a good starting point for differential diagnosis.

The classical presentation of plantar heel pain syndrome is that of a sharp pain under the medial heel that may radiate towards the arch. Symptoms are particularly severe upon rising in the morning (referred to as ‘first step pain’) and tend to subside after walking for a few steps. This is thought to be due to periods of inactivity causing the accumulation of oedema within the plantar tissues, which is dispersed by the action of the calf muscles when walking. Most commonly, symptoms are unilateral. Symptoms may vary depending on the tissue involved. In cases with nerve involvement, there may be evidence of neuritic symptoms (e.g.: burning, radiating pain), while cases with osseous involvement (such as insufficiency fracture of the calcaneus) do not generally subside after activity. Nocturnal pain may indicate less common causes such as tumours or infections.

## Aetiology
### Pathogenesis
The pathogenesis of plantar heel pain syndrome is poorly understood. Traditionally, heel pain was considered to be an inflammatory condition of the plantar fascia (hence the term plantar fasciitis) caused by excessive traction and subsequent microtears of the insertion of the plantar fascia into the calcaneus. Histological analysis of postsurgical specimens of the plantar fascia, however, indicate several degenerative changes (including fascial thickening, fibrosis, calcification and collagen necrosis) but no evidence of inflammatory cells. The presence of bony spurs within the plantar fascia or intrinsic musculature does appear to be more common in those with heel pain compared to controls and diagnostic imaging techniques have revealed several other structural changes in patients with heel pain, such as fat pad abnormalities, hyperaemia, adventitious bursae, calcaneal stress fractures, bone oedema and partial ruptures of the plantar fascia. Taken together, these findings suggest that heel pain results from a complex degenerative process involving multiple tissues rather than a purely inflammatory response of the plantar fascia. It is likely, however, that the pathological processes differ depending on whether the condition is acute or chronic.

### Risk factors
Several risk factors for plantar heel pain have been proposed, which can be summarised as intrinsic (including increased body mass index, limited ankle range of motion, limb length discrepancy, reduced

---

**Figure 10.1** Classification of heel pain syndrome.
heel pad thickness, excessive foot pronation and limited first metatarsophalangeal joint range of motion) and extrinsic (including long periods of weightbearing activity and inappropriate footwear). A recent systematic review of factors associated with heel pain summarized the results of 13 case-control and three case-series studies; a summary of the findings is shown in Table 10.1. Of the multitude of proposed risk factors, the factor with the highest level of evidence was increased body mass index/obesity, followed by increased age, decreased ankle dorsiflexion range of motion, decreased first metatarsophalangeal joint range of motion and prolonged standing. Each of these risk factors is consistent with the view that heel pain results from both the traction placed on the plantar fascia and compressive forces applied to the heel itself.

It should be noted, however, that many of these studies focused on plantar fasciitis rather than the broader concept of heel pain syndrome. Furthermore, few studies have specifically examined risk factors for heel pain in older people. Because of age-related differences in foot structure, particularly the increased stiffness of the plantar heel pad, it is likely that the relative importance of underlying risk factors for heel pain in older people may be somewhat different from the situation in younger people. In particular, it is likely that degenerative changes in the heel resulting from vertical compression play a larger role in the development of heel pain in older people. Furthermore, older people are also more likely to present with heel pain associated with an underlying systemic condition or infection.

### ASSESSMENT AND DIAGNOSIS

The accurate assessment and diagnosis of heel pain can be difficult, as no widely accepted diagnostic algorithm has been developed and at least 30 differential diagnoses have been reported in the literature. A provisional diagnosis can be reached from evaluating the location and characteristics of the pain and, in practice, most patients are considered to have plantar fasciitis (and are treated accordingly) unless proved otherwise. Table 10.2 (modified from Buchbinder) summarises clinical signs that point towards less common causes of heel pain.

Diagnostic imaging is not always necessary to confirm the diagnosis of plantar fasciitis but may play a role in excluding other potential diagnoses. Plain film X-rays will assist in ruling out calcaneal stress fractures and bony tumours; however, the observation of a calcaneal spur cannot be considered diagnostic, as approximately 15–40% of the general population have spurs, the prevalence of which is associated with increased age, obesity and osteoarthritis. In a recent study of 27 symptomatic patients and 79 controls, Osborne et al found that the combination of two observations from a lateral X-ray (plantar fascia thickness greater than 4 mm and presence of fat pad abnormalities) provided better differentiation between cases and controls than the presence of spurs.

Bone scanning of painful heels reveals increased blood flow and blood pooling at the insertion of the plantar fascia in a large number of cases and is thought to be indicative of osteoblastic activity associated with a periosteal reaction at the enthesis. Groshar et al compared 58 symptomatic and 28 asymptomatic feet and found that a positive bone scan had a sensitivity of 78% and specificity of 86% for the detection of clinically determined plantar fasciitis. However, increased uptake in the plantar heel region may also occur in the presence of stress fractures, osteomyelitis and tumours, so it is often difficult to delineate the contribution of specific structures from a positive bone scan.

Ultrasound imaging is not routinely used to diagnose plantar fasciitis; however, several studies have shown that people with heel pain demonstrate significant increases in the thickness of the plantar fascia (approximately 5–7 mm compared to the normal thickness of 2–4 mm). Furthermore, reduced echogenicity of the plantar fascia is more evident in people with heel pain and may provide greater discrimination than thickness measurements. In the Groshar et al study, evidence of hypoechoic regions

<table>
<thead>
<tr>
<th>Table 10.1 Factors associated with plantar heel pain</th>
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</thead>
<tbody>
<tr>
<td><strong>Factor</strong></td>
</tr>
<tr>
<td>Increased body mass index</td>
</tr>
<tr>
<td>Increased weight</td>
</tr>
<tr>
<td>Older age</td>
</tr>
<tr>
<td>Decreased ankle dorsiflexion ROM</td>
</tr>
<tr>
<td>Decreased first metatarsophalangeal joint extension ROM</td>
</tr>
<tr>
<td>Prolonged standing</td>
</tr>
<tr>
<td>Pronated foot posture</td>
</tr>
<tr>
<td>Reduced calf strength</td>
</tr>
</tbody>
</table>

ROM: range of motion
in the plantar fascia had a positive predictive value of 95% for heel pain compared to 84% for plantar fascial thickening, and demonstrated similar diagnostic accuracy to bone scanning.

Magnetic resonance imaging (MRI) has received only limited use in the diagnosis of heel pain; however, it may assist in the differentiation between plantar fasciitis and less common conditions. Calcaneal stress fractures, plantar fascial tears, plantar fibromatosis and capillary hemangioma of the heel can be clearly detected from MRI scans. MRI may also have a role in presurgical planning.

Less common causes of heel pain
A diagnosis of plantar heel pain syndrome accounts for the vast majority of plantar heel pain cases; however, there are several other conditions that may manifest as pain in the heel region, including systemic conditions (e.g. rheumatoid arthritis, diffuse idiopathic skeletal hyperostosis, hypertrophic osteoarthropathy, psoriatic arthritis and other seronegative spondyloarthropathies, gout and Paget’s disease), nerve entrapment, soft tissue and osseous tumours and infections. Nerve entrapments and tumours should be suspected in patients with longstanding heel pain that has not responded to conservative treatments. Definitive diagnosis will generally require diagnostic imaging and additional diagnostic tests (e.g. blood tests, synovial fluid analysis). A brief summary of these conditions is provided in Table 10.3; however, for further detail the reader is referred to recent comprehensive reviews by Selth & Francis and Burns et al.

### Table 10.2 Differential diagnosis of heel pain

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Distinguishing clinical features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plantar fasciitis</td>
<td>Morning pain</td>
</tr>
<tr>
<td></td>
<td>Pain on palpation of plantar fascia with toes dorsiflexed</td>
</tr>
<tr>
<td>Plantar fascia rupture</td>
<td>Sudden onset of pain</td>
</tr>
<tr>
<td></td>
<td>Inability to bear weight after activity</td>
</tr>
<tr>
<td></td>
<td>Bruising and swelling</td>
</tr>
<tr>
<td></td>
<td>Noticeable decrease in arch height compared to unaffected side</td>
</tr>
<tr>
<td>Calcaneal stress fracture</td>
<td>Develops after repetitive weightbearing exercise</td>
</tr>
<tr>
<td></td>
<td>Tenderness on mediolateral compression of the heel</td>
</tr>
<tr>
<td></td>
<td>Plain radiographs may indicate area of sclerosis</td>
</tr>
<tr>
<td>Paget’s disease</td>
<td>Bone pain elsewhere in body</td>
</tr>
<tr>
<td></td>
<td>Bowing of the tibia</td>
</tr>
<tr>
<td>Fat pad atrophy</td>
<td>Pain or tenderness in central heel region</td>
</tr>
<tr>
<td></td>
<td>Visible atrophy of plantar fibrofatty padding</td>
</tr>
<tr>
<td></td>
<td>No morning pain</td>
</tr>
<tr>
<td>Plantar calcaneal bursitis</td>
<td>Erythema and swelling of the plantar to posterior heel region</td>
</tr>
<tr>
<td>Medial calcaneal nerve entrapment</td>
<td>Burning pain, paraesthesia</td>
</tr>
<tr>
<td></td>
<td>Positive Tinel’s sign (radiating pain in response to nerve percussion)</td>
</tr>
<tr>
<td>Neuropathic heel pain</td>
<td>Diffuse pain</td>
</tr>
<tr>
<td></td>
<td>Nocturnal pain</td>
</tr>
</tbody>
</table>

**TREATMENT**

**Conservative**
A wide variety of conservative treatments have been described for heel pain. These can be broadly classified into three groups according to the aims of the treatment: (1) reduction of pain and inflammation, (2) reduction of soft tissue stress and (3) restoration of muscle strength and flexibility (Table 10.4). Anecdotally, conservative management is believed to
### Table 10.3 Less common causes of heel pain

<table>
<thead>
<tr>
<th>Classification</th>
<th>Disease/condition</th>
<th>Characteristic presentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systemic conditions</td>
<td>Rheumatoid arthritis</td>
<td>Bilateral heel pain, may be associated with plantar rheumatoid nodules and large calcaneal spurs</td>
</tr>
<tr>
<td></td>
<td>Diffuse idiopathic skeletal</td>
<td>Multiple painful entheses in the spine, shoulder, elbow, pelvis, knee and foot. Large, irregular calcaneal spurs with no evidence of erosion or periosteal reaction</td>
</tr>
<tr>
<td></td>
<td>hyperostosis</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hypertrophic osteoarthropathy</td>
<td>Acute unilateral heel pain with periostitis and increased bone density of the calcaneus, often accompanied by soft tissue swelling of the toes and clubbed nails</td>
</tr>
<tr>
<td></td>
<td>Psoriatic arthritis</td>
<td>Large, irregular calcaneal spurs with fluffy appearance, often accompanied by ‘sausage digits’ (fingers and toes)</td>
</tr>
<tr>
<td></td>
<td>Seronegative spondyloarthropathies</td>
<td>Symmetrical peripheral arthritis, soft tissue swelling, inflammation of calcaneal enthesis</td>
</tr>
<tr>
<td></td>
<td>Gout</td>
<td>Tophaceous deposits and associated erosive lesions of the calcaneus</td>
</tr>
<tr>
<td></td>
<td>Paget’s disease</td>
<td>Severe, continuous deep bone pain affecting the calcaneus</td>
</tr>
<tr>
<td>Nerve entrapment</td>
<td>May affect medial calcaneal,</td>
<td>Numbness, pins and needles and/or radiating pain that can be elicited by stroking the medioplantar region of the heel</td>
</tr>
<tr>
<td></td>
<td>medial plantar or lateral</td>
<td></td>
</tr>
<tr>
<td></td>
<td>plantar nerves</td>
<td></td>
</tr>
<tr>
<td>Soft tissue tumours</td>
<td>Soft tissue chondroma</td>
<td>Unilateral, circumscribed, firm, freely moveable subcutaneous mass on the plantar aspect of the heel. Pain aggravated by standing and relieved by rest</td>
</tr>
<tr>
<td>Osseous tumours</td>
<td>Intraosseous lipoma</td>
<td>No obvious physical signs. Unilateral, pain worse in mornings and relieved by rest. Pain can be elicited from lateral compression of the heel</td>
</tr>
<tr>
<td></td>
<td>Osteoid osteoma</td>
<td>Palpable mass, deep-seated pain that is worse in the evenings</td>
</tr>
</tbody>
</table>

### Table 10.4 Conservative treatments for heel pain

<table>
<thead>
<tr>
<th>Reduction in pain and inflammation</th>
<th>Reduction of tissue stress</th>
<th>Restoration of muscle strength and flexibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rest</td>
<td>Footwear modification/change</td>
<td>Calf muscle stretching</td>
</tr>
<tr>
<td>Reduction in activity</td>
<td>Strapping</td>
<td>Night stretch splints</td>
</tr>
<tr>
<td>Ice</td>
<td>Padding</td>
<td></td>
</tr>
<tr>
<td>Anti-inflammatory medications</td>
<td>Heel cups</td>
<td></td>
</tr>
<tr>
<td>Massage</td>
<td>Foot orthoses</td>
<td></td>
</tr>
<tr>
<td>Therapeutic ultrasound</td>
<td>Casting/bracing</td>
<td></td>
</tr>
<tr>
<td>Low-intensity laser</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Iontophoresis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Herbal medicine</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acupuncture</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extra-corporeal shockwave therapy</td>
<td></td>
<td></td>
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</tbody>
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be effective in the majority of cases; however, few detailed studies have been undertaken. A review of 250 heel pain patients by Weil et al\(^5\) claimed an 85% success rate with a standardised conservative treatment regimen consisting of activity modification, calf stretching, non-steroidal anti-inflammatory medications (NSAIDs), cortisone injection and customised foot orthoses. A somewhat lower success rate was reported by Taunton et al,\(^5\) with only 40% of 78 patients reporting 75% of greater improvement in symptoms following a similar conservative treatment approach. Finally, a long-term follow-up study of 100 conservatively-managed patients followed for an average of 4 years by Wolgin et al\(^5\) reported that 82% experienced complete resolution of their symptoms. No studies have specifically addressed success rates in older people. However, it is widely believed that the longer the duration of symptoms, the more difficult heel pain is to manage with conservative approaches.\(^5\)

The most recent Cochrane review of treatments for heel pain collated the results of 19 randomised controlled trials (RCTs) involving 1626 patients.\(^5\) Overall, the quality of many of the studies was poor. Nevertheless, there was some evidence for the efficacy of corticosteroid injection, limited evidence for topical corticosteroid administered by iontophoresis, dorsiflexion night splints and foot orthoses, and no evidence to support the efficacy of therapeutic ultrasound, laser or magnetic insoles. Brief summaries of the evidence for these treatments are provided below.

Corticosteroid injections have been evaluated in three published randomised controlled trials,\(^5\) of which reported significant long-term reductions in pain compared to a placebo. However, Crawford et al\(^5\) reported a small but statistically significant reduction in pain at 1 month follow-up. The efficacy of repeated injections over a prolonged period is uncertain, although, given that there have been reports of plantar fascial rupture associated with long-term corticosteroid use,\(^5\) it appears that corticosteroid injection is best reserved for short-term pain relief.

Dorsiflexion night splints are worn while sleeping and align the ankle in a neutral or dorsiflexed position while the metatarsophalangeal joints are also dorsiflexed, thereby causing a gradual passive stretch of the calf muscles and the plantar fascia. The efficacy of this treatment approach is uncertain, as, although one crossover trial reported significant reductions in pain,\(^5\) another trial failed to show such a benefit.\(^5\) Furthermore, night splints are not well tolerated by many patients, as they are cumbersome and may interfere with normal sleeping patterns. In one study, 19% of the patients reported dissatisfaction with this treatment approach.\(^5\)

Active calf muscle stretching, although commonly used as an adjunct treatment in clinical practice, does not appear to be effective in isolation. Radford et al\(^5\) compared 2 weeks of daily calf stretching versus sham ultrasound and found no significant differences in pain reduction between the two groups.

A variety of foot orthoses are used for the management of plantar heel pain, including prefabricated insoles, customised orthoses and various cushioning devices. Two trials found no benefit of magnetic insoles over simple cushioning insoles,\(^5\) while four trials comparing prefabricated orthoses to custom orthoses reported quite variable findings. Lynch et al\(^5\) compared (1) low-Dye taping followed by custom foot orthoses to (2) an accommodative visco-elastic heel insert and (3) corticosteroid injection followed by NSAIDs and found that the custom orthoses/taping group demonstrated greater reductions in pain after 3 months. Similarly, Turlik et al\(^5\) reported that ‘functional’ orthoses were more effective than cushioned heel pads. In contrast to these findings, Martin et al\(^5\) found no differences between prefabricated orthoses, customised orthoses and dorsiflexion night splints, and Pfeffer et al\(^5\) found that prefabricated orthoses were more effective than customised orthoses or stretching.

Since the publication of the Cochrane review, two key RCTs have been reported in the literature relating to mechanical treatments. Radford et al\(^5\) randomised 92 people with heel pain to receive either low-Dye taping or sham ultrasound and found that the taping group reported a small but significant reduction in first-step pain after 1 week compared to the sham group. Landorf et al\(^5\) compared semi-rigid customised orthoses to prefabricated orthoses and a sham insole and found that, while both the customised and prefabricated orthoses improved function to a similar degree at 3 months, no significant differences between the three groups for pain or function were noted at 12 months, suggesting that plantar heel pain may be self-limiting. This paper also included a meta-analysis of their results combined with three similar trials (Lynch et al,\(^5\) Pfeffer et al and Martin et al\(^5\)), which indicated no significant benefit of custom orthoses over prefabricated orthoses. Taken together, these findings suggest that the treatment regimen com-
commonly employed by podiatrists (taping followed by orthoses) is effective in the short term; however, there appears to be no benefit of custom orthoses over prefabricated orthoses.

The efficacy of shock-absorbing heel pads and rigid heel cups has not been rigorously evaluated; however, it is likely that rigid heel cups may be of particular value in managing heel pain in older people. As stated previously, it has been shown that ageing is associated with significant increases in the stiffness of the plantar heel pad due to breakdown of the fibrous septa and a subsequent increase in lateral expansion when weightbearing. By confining the lateral expansion of the heel pad with rigid heel cups, the vertical thickness of the pad is maintained, which may enhance shock absorption and prevent further damage to soft tissue structures in the plantar heel region. Uncontrolled studies have reported good clinical results with the use of rigid heel cups in patients with ‘bruised heels’ and it is possible that circumferential taping around the heel has a similar effect.

The effectiveness of extracorporeal shockwave therapy is uncertain. This relatively new treatment involves the transcutaneous application of shockwaves into the heel region with the aim of stimulating healing of the enthesis and inhibiting pain receptors. Of the eight RCTs that have been conducted, three showed no benefit and five reported small reductions in pain when compared to a placebo. These findings, however, need to be viewed with some caution. Firstly, the generalisability of these findings is limited, as inclusion into four of these studies required the positive identification of a calcaneal spur from X-ray. Secondly, many of these trials were of low quality, with a tendency towards lower-quality trials and trials funded by shock-wave device manufacturers reporting more favourable outcomes. It is also worth noting that extracorporeal shockwave therapy without local anaesthesia is generally considered to be painful. In one study, 79% of people reported pain during treatment.

**TIBIALIS POSTERIOR DYSFUNCTION**

**CLASSIFICATION AND CLINICAL PRESENTATION**

Tibialis posterior dysfunction (TPD) is a condition in which the tendon of the tibialis posterior muscle becomes weak and elongated, leading to a progressive, painful flat foot deformity (Fig. 10.2). Although the prevalence is unknown, the condition most commonly affects middle-aged and elderly women. The classical features of TPD are a progressive flattening of the foot, tenderness and swelling along the tibialis

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**Surgical**

Surgery for heel pain is generally only considered appropriate for a select group of patients who have had severe, chronic pain and have failed to respond to several conservative treatments. Numerous techniques have been described, involving total or partial release of the plantar fascia with or without resection of the calcaneal spur and tibial nerve decompression. Although case series studies indicate very high levels of patient satisfaction (ranging from 81% to 94%), no randomised trials have been undertaken. Recovery from surgery may take several months and complications including scarring, medial arch pain, cramping and calcaneal fracture have been reported in up to 10% of patients. Surgical intervention for heel pain should be very carefully considered in older people because of prolonged recovery times and the increased risk of acquired flat foot deformity.

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**Figure 10.2A, B Pes planus (flat foot). (A, courtesy of Lloyd Reed, Queensland University of Technology.)**
posterior tendon as it passes behind the medial malleolus, and reported difficulty in walking on uneven surfaces. However, there is a broad spectrum of TPD severity, which has led to the development of several classification systems. Johnson & Strom proposed three stages, Myerson added a fourth stage incorporating arthritic changes in the ankle joint, Mueller proposed a different four stage classification system incorporating an asymptomatic stage, and Wainwright et al. have proposed a classification system based on MRI findings. The modified scale reported by Myerson is provided in Table 10.5.

### AETIOLOGY

The pathogenesis of TPD is poorly understood. Histological studies of affected tendons demonstrate features of chronic tendon degeneration accompanied by fibrosis but no evidence of inflammatory cells. These changes are thought to result from repeated microtrauma caused by excessive strain placed on the tendon in the presence of mild flat foot. Vascular factors may also play a role, as a hypovascular region in the tendon has been identified posterior and inferior to the medial malleolus, where the tendon is firmly tethered by the flexor retinaculum. Ligamentous damage is frequently observed in advanced cases, with the spring ligament complex being particularly affected. However, whether the tendon dysfunction precedes ligament damage or vice versa remains unclear. No case-control studies have been conducted to ascertain the risk factors associated with TPD; however, case series studies indicate that the condition appears to be associated with advancing age, female sex, obesity and hypertension. TPD may also be a cause of flat foot deformity in people with rheumatoid arthritis.

As TPD progresses, the arch becomes progressively lower, the calcaneus everts and the forefoot abducts relative to the rearfoot. This change in foot posture results in significant alterations to the weightbearing function of the foot, characterised by increases in rearfoot eversion, increased medial plantar pressure distribution (Fig. 10.3), and increased electromyographic activity of the tibialis posterior muscle. Over time, the altered function of the foot often results in arthritic degeneration of the joints of the midfoot and rearfoot.

### ASSESSMENT AND DIAGNOSIS

The assessment of TPD is relatively straightforward, as a diagnosis can be reached on the basis of history taking and physical examination. In the early stages, patients will report a vague, insidious pain around the medial malleolar region. As the condition progresses, patients may also report noticing changes in the shape of the affected foot and difficulty performing certain activities, such as walking up stairs or over uneven ground. In advanced cases, the foot becomes markedly everted and pain may develop in the lateral ankle region as the calcaneus abuts against the distal fibula. A recent study of 65 older people indicated that positive responses to two statements on a questionnaire – regarding the presence of pain and swelling in the medial ankle region and observations of changes in the shape of the foot – detected 100% of patients who had been clinically diagnosed with TPD, with a specificity of 98%.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Features</th>
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| 1     | Tendon inflamed  
No change in foot shape |
| 2     | Tendon elongated  
Acquired flat foot deformity |
| 3     | Fixed deformity  
Degenerative changes at subtalar joint |
| 4     | Fixed deformity  
Degenerative changes at subtalar and ankle joints |

Figure 10.3 Typical plantar pressure output of a patient with tibialis posterior dysfunction.
Several clinical tests can assist in the diagnosis of TPD. Visual observation will reveal signs of pes planus (flat foot deformity), with a lowering of the longitudinal arch (Fig. 10.2A). Viewed from behind, the affected foot may demonstrate the ‘too many toes’ sign, in which three or more toes can be viewed lateral to the heel as a result of abduction of the forefoot.87 Patients will have difficulty rising on to their toes, and a loss of heel inversion when performing this task may also be evident. Manual muscle testing of the tibialis posterior muscle strength will also reveal marked weakness on the affected side.84,86,100

Diagnostic imaging is not necessary to confirm a diagnosis of TPD but may be worthwhile to visualise the extent of tendon damage or to quantify the extent of the deformity. Plain film radiographs are useful for assessing deformity and the severity of osteoarthritic changes, and to exclude other possible causes.101 Lateral X-rays will reveal a decreased calcaneal inclination angle, increased calcaneal-first metatarsal angle and a break in the cyma line (Fig. 10.2B). Anteroposterior X-rays are less helpful but will reveal forefoot abduction and degenerative changes in the midfoot joints.84,102 Ultrasound will reveal increased tendon diameter and evidence of echogenic areas within the tendon.103 MRI can detect discontinuity in the tendon but does not confer any substantial benefit over ultrasound and is generally only used for presurgical planning.104–107

**TREATMENT**

**Conservative**

Conservative treatment of TPD involves measures for pain relief, mechanical interventions to control the deforming forces on the foot, and strengthening exercises. Initial treatment should involve the prescription of NSAIDs and the application of rigid adhesive taping, which has been shown to significantly control foot pronation.108 Extending tape stirrups above the ankle (so-called ‘high-Dye’ taping) may be more effective in controlling total range of motion than low-Dye taping.109 Longer-term management includes the prescription of rigid foot orthoses and appropriate supportive footwear, strengthening exercises using graduated elastic exercise bands and, in severe cases, ankle–foot orthoses (AFOs).84,86,100–102 Corticosteroid injection is generally not recommended because of the increased risk of tendon rupture with prolonged use, but may be useful if combined with cast immobilisation or removable walking casts to discourage excessive weightbearing activity.

No RCTs of these treatments have been undertaken, so their efficacy is uncertain. However, two case series studies have reported favourable results. Wapner & Chan110 found that 67% of patients were satisfied with non-operative treatment, which in most cases consisted of the UCBL shoe insert. Similarly, Jari et al111 reported that a non-surgical management approach (consisting of NSAIDs, icing, therapeutic ultrasound, strengthening exercises, UCBL shoe inserts and AFOs) was effective in 23 out of 28 patients followed up for two years.

**Surgical**

Surgical management of TPD varies according to the stage of the condition. Stage I TPD is generally managed with synovectomy and tendon debridement/repair in conjunction with calcaneal osteotomy to correct the foot into a more supinated position. Stage II TPD is treated in a similar manner, with the addition of tendon transfer (either flexor digitorum longus112,113 or a split tibialis anterior114) to assist in the antipronation function of tibialis posterior. Surgical management of stage III TPD generally involves triple arthrodesis (fusion of the subtalar, calcaneocuboid and talonavicular joints), while stage IV often requires pantalar arthrodesis (fusion of the ankle subtalar, calcaneocuboid and talonavicular joints).86,101 As with conservative treatments, no controlled trials of these surgical techniques have been undertaken. However, case series studies have reported good to excellent results in 80% of patients.85,113,115 Recovery may take several months and will frequently require a below-knee plaster cast.86

**RETCALCANEAL CONDITIONS**

Pain in the posterior region of the heel is less common than plantar heel pain, and subsequently has received relatively little attention in the literature. As with plantar heel pain, retrocalcaneal pain can be considered to be a syndrome which encompasses a variety of pathological entities that often present concurrently. Although accurate prevalence data is unavailable, the most common conditions affecting the posterior aspect of the heel in older people appear to be Haglund’s deformity (with or without retrocalcaneal bursitis) and Achilles tendinopathy, while less
common causes include soft tissue manifestations of arthritic conditions (such as rheumatoid nodules) and soft tissue cysts and tumours.

## HAGLUND’S DEFORMITY

### Definition and aetiology

Haglund’s deformity, also known as pump bumps, winter heel, achillodynia, retrocalcaneal bursitis and cucumber heels, was first described by Patrick Haglund in 1928.\(^\text{116}\) Haglund reported a case of a 20-year-old woman with pain located in the posterosuperior aspect of the heel accompanied by a bony enlargement at the insertion of the Achilles tendon, which he attributed to the wearing of shoes with a rigid heel counter.

In 1945, Fowler & Philip\(^\text{117}\) proposed that patients with the condition exhibited a structural anomaly of the calcaneus, in which the angle formed between the plantar surface of the calcaneus and the most posterior projections of the bursal surface (now known as Fowler–Philip’s angle or FPA) is increased. In such a foot, there is a greater tendency for the heel to become compressed against the shoe, leading to inflammation of the superficial tendo achillis or retrocalcaneal bursa, the formation of a retrocalcaneal exostosis and subsequent overlying hyperkeratosis.

Subsequent studies have largely supported this view;\(^\text{118}\) however, there is some debate regarding the angle at which the foot is susceptible to the development of the deformity, and preliminary evidence that other radiographic measurements may be more highly predictive than the FPA. Ruch\(^\text{119}\) reported on 65 surgical cases of Haglund’s deformity and found that only seven exhibited a FPA greater than 75°. However, the calcaneal inclination angle (CIA) ranged from 20–50°, suggesting that a combination of the FPA and the CIA may provide a more accurate indicator of the structural anomaly of the calcaneus responsible for the condition. Vega et al\(^\text{120}\) reviewed 20 cases and suggested that the summation of the FPA and CIA (referred to as the ‘total angle’) ranges from 85° to 97° in people with Haglund’s deformity, compared to a normal range of 64–89°. More recently, a large study by Mishra et al\(^\text{121}\) of 117 cases and 72 controls indicated that the CIA was more strongly correlated with Haglund’s deformity than the FPA. The authors also proposed a new measurement, the calcaneal body index (the ratio between the maximum height of the posterior and anterior body of the calcaneus) as a possible aetiological factor, suggesting that people with a ‘tall’ calcaneus may be predisposed to developing the deformity. A summary of radiographic angles of relevance to Haglund’s deformity is shown in Figure 10.4.

The role of footwear is unclear. Several authors suggest that shoes with a rigid heel counter or tight heel straps may cause irritation in those predisposed to the condition\(^\text{116,120,122,123}\) and indeed, an electrodynographic study by Rzonca et al\(^\text{124}\) confirmed that the forces applied to the posterosuperior aspect of the heel during gait were significantly larger in those with Haglund’s deformity than in controls. However, only 13% of the 117 cases in the Mishra et al\(^\text{121}\) study wore shoes on a regular basis, indicating that the condition can also develop in barefooted individuals.

### Clinical presentation

The classical presentation of Haglund’s deformity is that of pain and inflammation around the posterior...
heel, accompanied by superficial bursitis and an osseous and soft tissue prominence in the region of the Achilles tendon insertion (Fig. 10.5). There may be evidence of direct abrasion from the upper edge of the shoe heel counter. In older people, the condition is frequently associated with an overlying region of hyperkeratosis, which may become ulcerated. Pain may be elicited by direct pressure on the posterior prominence or by dorsiflexing the ankle.

Assessment and diagnosis

A provisional diagnosis of Haglund’s deformity can be reached from thorough history taking, clinical observation and physical examination. Detailed assessment of footwear (both indoor and outdoor) is essential, not only to determine its possible contribution to the presenting complaint but also to assess the suitability of the shoes for modification and/or accommodation of offloading devices. Systemic conditions that may manifest as soft tissue masses in the posterior region of the heel, such as rheumatoid arthritic nodules and tophaceous gout deposits, first need to be ruled out.125

Lateral weightbearing X-rays are very useful to rule out other conditions (such as soft tissue and osseous tumours41), to determine the magnitude of the posterior exostosis and to evaluate the contribution of calcaneal morphology to the development of the condition. Ultrasound is not necessary to confirm a diagnosis but may reveal signs of Achilles tendinopathy, bursitis and ossification of the insertion of the Achilles tendon.126,127 Similarly, MRI is rarely used but may assist in differentiating between normal and abnormal retrocalcaneal bursae. A recent case-control study indicated that retrocalcaneal bursae larger than 1 mm anteroposteriorly, 11 mm transversely, or 7 mm dorsoplantarly can be considered abnormal.128

Foot posture assessment and gait analysis may be useful, as several authors have suggested that excessive rearfoot motion may lead to friction between the prominence and the heel counter of the shoe. In particular, compensation for an inverted rearfoot deformity has often been implicated in the development of Haglund’s deformity.129

Conservative treatment

Conservative management of Haglund’s deformity involves removing the potential cause (by exchanging or modifying footwear), pain management (such as NSAIDs or corticosteroid injection), pressure redistribution (via the use of apertured pads or silicone shields) and techniques to alleviate tension at the Achilles tendon insertion (such as heel lifts, foot orthoses and gastrocnemius stretching).120,129-131 Corticosteroid injection needs to be carefully performed to ensure that the injection is directed into the inflamed bursa and not into the tendon itself, because of the risk of rupture. A single injection of cortisone mixed with local anaesthetic has been reported to be clinically effective.129 However, no rigorous studies have been undertaken to assess the efficacy of these techniques and it has been suggested that conservative management of Haglund’s deformity is only effective in very mild cases120,122,132 and is associated with a high recurrence rate.131,132

Surgical treatment

Surgical management of Haglund’s deformity involves removal of the retrocalcaneal prominence via bursectomy, exostectomy, calcaneal osteotomy or, most frequently, a combination of these methods.122 Several different incisional approaches have been described (Fig. 10.6). The direct posterior approach allows direct access to the superficial bursa and is technically quite simple to perform. However, to remove the exostosis, the Achilles tendon must be excised and reattached, which may lead to weakening or rupture of the tendon postoperatively. The longitudinal linear incision avoids this potential problem; however, this approach does not allow for ease of access to the superficial bursa. A modification of this approach, the lazy-L incision, improves access to the superficial
bursa and leads to less skin contracture postoperatively.\textsuperscript{120} Finally, an endoscopic technique has also been recently described, which involves a small medial or lateral incision guided by fluoroscopy.\textsuperscript{132}

In most cases, a simple ostectomy is performed, which involves removing the offending portion of bone and smoothing the edges with a rasp or rongeur. However, in severe cases (particularly those with a large exostosis and/or a large calcaneal inclination angle) a wedge osteotomy may be considered. This approach, first described by Zadek in 1939,\textsuperscript{133} involves removing a dorsal wedge of bone from the calcaneus and closing the incision with cancellous bone screws (Fig. 10.7). This technique requires a longer period of cast immobilisation following surgery\textsuperscript{131} and may therefore not be appropriate for older patients. Complications associated with both techniques include recurrence due to inadequate bone resection, Achilles tendon weakening and/or rupture, scar formation and subsequent nerve entrapment and, in the case of osteotomy, non-union and pseudoarthrosis.\textsuperscript{122}

Although highly favourable outcomes have been reported in case series studies of Haglund’s deformity surgery with small samples and/or a short duration of follow-up,\textsuperscript{132,134–136} longer-term follow-up studies have seriously questioned the efficacy of surgical intervention.\textsuperscript{137,138} Taylor\textsuperscript{137} followed up 42 patients who had undergone closing wedge calcaneal osteotomy over a 6–7-year period and found that 46% were dissatisfied following the procedure. The most common reasons for dissatisfaction were residual prominence (51%), widening of the scar (48%) and altered sensation (38%). Similarly, a 4–5-year follow-up of 49 patients by Schneider et al\textsuperscript{138} reported complete resolution of symptoms in 34 patients; however, seven reported a worsening of symptoms. Furthermore, the rehabilitation period was an average of 6 months and few patients reported that they would be willing to undergo a similar procedure again. Better long-term results were reported by Brunner et al\textsuperscript{139} in 36 patients followed up for 4 years; however, the recovery time ranged from 6 months to 2 years. On the basis of these findings, it is generally recommended that all conservative approaches be tried before considering surgical intervention and that, when considering surgery, patients need to be advised of the potentially prolonged period of recovery.

\section*{ACHILLES TENDINOPATHY}

\subsection*{Definition and aetiology}

Achilles tendinopathy is one of the most common overuse injuries in athletes and can be defined as the symptomatic overuse, degeneration and failed repair of the Achilles tendon.\textsuperscript{140} While early reports considered the condition to be inflammatory (hence the
term *Achilles tendinosis*), it is now recognised that the pathological process is far more complex and that chronic tendinopathy does not involve inflammatory cells.\(^141\) Although most commonly observed in young and middle-aged athletes, Achilles tendinopathy may also occur in physically active\(^142,143\) or sedentary older individuals.\(^144\) As outlined in Chapter 2, there are several age-related changes in the physiology of tendon tissue, including increased collagen crosslinking,\(^145\) decreases in water content\(^146\) and increased in lipid content.\(^147\) These changes may predispose to tendinopathy in physically active older people, as a recent study of young and older athletes indicated that Achilles tendon problems were more common in the older group (20% versus 5% of all injuries).\(^148\) Age is also recognised as a strong negative predictor of outcome in surgical repair of Achilles tendon disorders.\(^149,150\)

The aetiology and pathophysiology of Achilles tendinopathy is poorly understood. Several risk factors have been identified, including obesity,\(^151\) sudden increases in the duration and intensity of weightbearing activity\(^152\) and decreased ankle dorsiflexion range of motion (leading to an increase in strain on the tendon).\(^153\) Broadly speaking, three theories have been put forward in relation to the pathophysiology of Achilles tendinopathy.\(^154\) The *mechanical* theory suggests that repeated loading of the tendon causes gradual fatigue and subsequent microscopic degeneration. The *vascular* theory suggests that the cause of tendon degeneration is a reduction in blood supply in the inherently hypovascular midportion of the tendon.\(^155\) However, the inverse has also been proposed, i.e. that exercise-induced hyperthermia may be detrimental to tendons.\(^156\) Finally, a *neural* theory has recently been proposed in response to the observation of glutamate (a neurotransmitter) in damaged tendons\(^157\) and the reported association between Achilles tendinopathy and sciatica.\(^158\)

Several medications have also been implicated in degeneration and rupture of the Achilles tendon, particularly corticosteroids\(^159\) but also fluoroquinolone antibiotics\(^151,160\) and statins.\(^161\) The role of medications in predisposition to Achilles disorders is of particular importance in older people. A recent study of 1367 cases and 50,000 controls indicated that, in people over 60 years of age, the use of quinolone antibiotics significantly increased the likelihood of experiencing an Achilles tendon rupture and that this risk was further increased in those who were also taking corticosteroids.\(^162\)

Irrespective of the underlying cause, histological examinations of affected tendons have revealed several characteristic changes, including irregular arrangement of collagen fibres, increased vascularity and evidence of delayed healing.\(^163,164\) In addition to these changes, ruptured tendons also exhibit inflammatory lesions and the presence of granulation tissue.\(^165\)

### Assessment and diagnosis

Most of the information required to diagnose Achilles tendinopathy can be obtained from a thorough patient history and physical examination. The primary presenting complaint is pain 2–6 cm proximal to the insertion of the tendon, which is exacerbated by physical activity and relieved by rest. The tendon may be diffusely swollen and palpable nodules may be present when the ankle is dorsiflexed and plantarflexed.\(^166\) Retrocalcaneal bursitis or Haglund’s deformity may also be present. Patients who have sustained an acute rupture of the tendon will typically report a sudden onset of pain accompanied by an audible snap at the time of injury and will be unable to bear weight on the affected limb. Patients with chronic ruptures, however, may report only minor or no trauma and often recall difficulty climbing stairs as the initial symptom.\(^167\)

Achilles tendinopathy may be differentiated from rupture by conducting either of two simple tests. The *calf-squeeze test*, also known as the *Thompson test*, was first described by Simmonds in 1957\(^168\) and involves squeezing the fleshy part of the calf while the patient is lying prone. If the Achilles tendon is intact, this test will result in plantarflexion of the ankle joint, whereas in the presence of a ruptured tendon no ankle movement will be elicited. The *knee flexion test* involves the patient flexing the knee to 90° while lying prone. In the presence of an Achilles tendon rupture, the foot will drop into a neutral or dorsiflexed position.\(^169\)

Diagnostic imaging is not necessary for routine clinical diagnosis but is considered useful for presurgical planning.\(^170\) Plain film X-ray is not widely used in the diagnosis of tendinopathy but may be useful in cases of insertional tendinopathy where bony spurs are suspected. Ultrasound imaging of abnormal Achilles tendons will reveal tendon enlargement and hypoechoic regions;\(^171\) however, false-positive findings are common in mild to moderate cases\(^172\) and differentiating between tendon degeneration and
partial rupture is difficult. MRI will typically reveal tendon and paratenon thickening, peritenon fluid accumulation and edema of Karger’s fat pad. As with ultrasound, however, there is considerable overlap between the appearance of normal and abnormal tendons. Neither the use of ultrasound nor MRI has been shown to predict clinical outcomes of surgical intervention.

**Conservative treatment**

Several conservative treatments have been trialled in the management of Achilles tendinopathy, including anti-inflammatory medications, calf stretching, massage, therapeutic ultrasound, laser, cryotherapy, corticosteroid injections, strengthening exercises, heel lifts and foot orthoses. However, because of the limited understanding of the underlying cause of the condition, treatment is largely empirical and varies considerably among clinicians. Furthermore, few of these techniques have been evaluated in randomised controlled trials and no trials have specifically been undertaken in older people.

Initial conservative management of Achilles tendinopathy involves pain relief, via the use of anti-inflammatory medications, cryotherapy and/or corticosteroid injections. Anti-inflammatory medications are likely to only be of benefit in the acute phase, as chronic degenerative tendinopathy is not an inflammatory condition. Indeed, a randomised trial found that piroxicam offered no benefits over a placebo medication in 70 patients with chronic Achilles tendinopathy. The use of corticosteroids is somewhat controversial, as there is some evidence that peritenon injection of cortisone delays tendon healing and several cases of spontaneous rupture following corticosteroid injection have been reported. More recently, techniques designed to sclerose small blood vessels within the tendon (by the use of polidocanol or electrocoagulation) have been trialled with some success; however, larger studies with longer-term follow-up are now required.

Longer-term conservative management of Achilles tendinopathy is aimed at restoring the normal function of the musculotendinous unit to prevent recurrence. Strengthening the triceps surae muscle group using eccentric loading exercises has been shown to be effective in managing Achilles tendinopathy in athletic populations; however, whether this approach is safe and effective in older people remains unclear.

The effectiveness of orthomechanical therapies (such as heel lifts and foot orthoses) has not been examined in detail; however, a randomised controlled trial of heel lifts did not provide any substantial clinical benefit when added to a treatment regimen of stretching, strengthening and ultrasound.

The most recent Cochrane review of nine randomised trials involving 697 patients concluded that, while there was weak evidence for the use of nonsteroidal anti-inflammatory medications in alleviating symptoms in acute tendinopathy, there is currently insufficient evidence to guide conservative treatment of chronic Achilles tendinopathy. Despite this lack of evidence, the long term prognosis of conservative management appears to be quite good. An 8-year follow-up of 83 patients managed with various conservative approaches indicated that the vast majority (94%) were asymptomatic or reported only mild pain when exercising.

**Surgical treatment**

Surgical intervention for Achilles tendinopathy is only indicated when conservative methods have failed. Although various surgical techniques have been described, most involve debridement of degenerated tendon tissue, removal of adhesions between the tendon and paratenon and, in the case of intratendinous lesions, longitudinal incision and excision of granulation tissue. Partial ruptures may require suturing or grafting. Clinical success rates of between 75% and 100% have been reported in retrospective studies; however, few have used objective outcome measures. Complications, such as residual strength deficits and delayed healing, have been reported in approximately 10% of cases.

Acute ruptures of the Achilles tendon generally require open operative repair with suturing or tendon grafting techniques, followed by cast immobilisation for 4–8 weeks. Although some authors suggest that older patients are best managed non-operatively, using cast immobilisation or functional bracing, good results with flexor hallucis longus transfer have been reported in five patients aged 52–71 years of age. The recent Cochrane review of 14 trials involving 891 patients indicated that surgical management of acute ruptures was associated with a lower risk of re-rupture; however, those treated non-operatively experienced fewer complications and required shorter periods in hospital.
OSTEOARTHRITIS OF THE MIDFOOT AND REARFOOT

PREVALENCE AND RISK FACTORS

Osteoarthritis is the most common form of arthritis and is the leading cause of disability in developed countries. The prevalence of osteoarthritis increases significantly with age. Approximately 28% of people aged over 65 years report symptomatic osteoarthritis, with prevalence increasing to 37% in people aged over 85 years. Older people with osteoarthritis are more likely to have difficulties with activities of daily living, reduced quality of life and increased risk of falls compared to those without the condition. The most commonly affected joints are the hips, knees and lumbar spine, and in Australia it has been estimated that 19,000 hip and 20,000 knee replacements are performed for osteoarthritis each year.

In contrast to the wealth of literature pertaining to hip and knee osteoarthritis, relatively little is known about osteoarthritis affecting the foot in older people. In the US, the 1991 National Health Interview Survey included a podiatry supplement and found that approximately 6% of respondents over 65 years of age reported ‘arthritis of the toes’, while a recent postal survey of 5689 people over 65 years of age in the Netherlands reported that 8% of subjects reported ‘foot osteoarthritis’. The prevalence of radiographically confirmed osteoarthritis in the midfoot and rearfoot is largely unknown, as the two largest radiographic prevalence studies that included foot joints primarily focused on the metatarsophalangeal joints. However, a study of 50 cadavers (average age at death of 76 years) indicated that moderate to severe degenerative changes were evident in the subtalar joint in 67% of cases and the transverse tarsal joint (i.e. talonavicular and calcaneocuboid joints combined) in 50% of cases.

Although several risk factors for osteoarthritis in other joints have been identified (such as increased age, family history, obesity and occupation), little is known about risk factors for primary foot osteoarthritis. The observation that foot osteoarthritis frequently coexists with osteoarthritis in the hands and knees suggests that a systemic aetiology with genetic predisposition may be responsible. There is also preliminary evidence that this hereditary predisposition may be related to anatomical variations in articular facet configuration. An anatomical study of 191 osteological specimens by Drayer-Verhagen found that calcanei with a large, continuous anterior facet were more likely to demonstrate arthritic lipping, suggesting that the increased range of motion associated with this articular configuration may cause the joint to be less stable, thereby predisposing to the development of subtalar joint osteoarthritis (Fig. 10.8).

Secondary osteoarthritis affecting the subtalar joint and midfoot joints is a relatively common complication of ankle joint fusion. In one study, 33% of patients who had undergone ankle arthrodesis developed subtalar joint osteoarthritis after an average of 7 years of follow-up. The underlying mechanism appears to be an increase in joint contact pressures during the propulsive phase of gait, as a recent cadaver study revealed that talonavicular and calcaneocuboid pressures were significantly increased following ankle arthrodesis when the ankle joint was placed between 0° and 20° of dorsiflexion.

Figure 10.8 Variations in the anterior articular configuration of the calcaneus. A. Two separate anterior facets. B. Continuous figure-eight facet. C. Long continuous facet. D. Medial facet only.
CLINICAL PRESENTATION

Osteoarthritis affecting the midfoot and rearfoot generally presents as a vague, insidious pain in the midfoot region that is exacerbated by long periods of weightbearing activity. Overt signs of inflammation are generally absent; however, there may be mild swelling around the affected joint or joints. Palpation of the affected area may reveal the presence of large osteophytes at the margins of the joint, and pain may be elicited in response to moving the joint through its full range of motion. Plain film X-rays will reveal the characteristic features of osteoarthritis, including joint space narrowing, formation of osteophytes, subchondral sclerosis and bony cysts. Typical examples are shown in Figure 10.9. A recently published atlas of osteoarthritis affecting the foot is a useful guide for grading the severity of arthritic changes.202

CONSERVATIVE TREATMENT

Conservative management of foot osteoarthritis is similar to that of osteoarthritis in other weightbearing joints and includes the use of analgesics for pain relief and mechanical therapies to reduce the compressive load on the affected joint. Although no rigorous studies have been undertaken, foot orthoses may be effective in patients with osteoarthritis related to flat foot deformity (such as those with tibialis posterior dysfunction). There is preliminary evidence that cast orthoses may be more effective in managing symptoms associated with foot osteoarthritis than nonsteroidal anti-inflammatory medications.203 In this retrospective study, the degree of pain relief reported by 64 patients (average age 63 years) who had received various treatments for foot osteoarthritis were evaluated. All of those who were prescribed foot orthoses reported significant reductions in pain, and their pain relief was maintained for a longer period of time than those who were taking NSAIDs. Although there are several limitations with this type of study design, it is worth noting that foot orthoses reduce subtalar joint pronation204 and foot pain205 in patients with rheumatoid arthritis, so it is possible that they may have similar effects in people with osteoarthritis.

Figure 10.9 Radiographic appearance of osteoarthritis. A. First cuneometatarsal joint. B. Navicular–cuneiform joint. C. Talonavicular joint.
In patients with more advanced degenerative osteoarthritis of the subtalar and ankle joints, ankle–foot orthoses may be effective. Several studies in patients with subtalar and ankle osteoarthritis have confirmed that various designs of ankle–foot orthoses are effective in reducing rearfoot motion and may therefore relieve compression in the midfoot and rearfoot. Ankle–foot orthoses are discussed in more detail in Chapter 11.

**SURGICAL TREATMENT**

Surgical management of rearfoot and midfoot osteoarthritis in older people generally involves fusion of the affected joint or joints. Traditionally, most cases were treated with triple arthrodesis (fusion of the ankle, subtalar and transverse tarsal joints); however, more recently, single joint fusions are undertaken in an attempt to preserve as much motion as possible and arthroscopic debridement has also been used as an interim approach before considering arthrodesis. Although no controlled trials have been undertaken, several case series studies indicate that arthrodesis is an effective treatment for advanced osteoarthritis and that most patients are satisfied with the results. However, foot function is markedly altered following surgery and many patients will exhibit gait changes associated with their reduced range of motion. In particular, many patients report difficulties walking on irregular surfaces following arthrodesis and, as stated previously, up to one-third may develop secondary osteoarthritis in adjacent joints. Furthermore, in most surgical studies a large number of patients report some degree of residual pain and require adjunctive conservative treatments such as footwear modifications and orthoses.

**LESS COMMON MIDFOOT AND REARFOOT DISORDERS**

**PAINFUL PES CAVUS**

The term *pes cavus* describes a foot with an abnormally high medial arch (Fig. 10.10) and therefore refers to a structural anomaly rather than a discrete clinical condition. Not all people with highly arched feet develop symptoms. However, the features commonly associated with pes cavus, such as restricted joint range of motion and loss of shock absorption, are associated with elevated pressures in the forefoot and heel (Fig. 10.11), which may contribute to the development of plantar forefoot and heel pain. Because of the trend towards a lowering of the medial arch with advancing age, pes cavus is not a common presentation in older people. The Feet First study of 784 Americans aged over 65 years reported a 5% prevalence of pes cavus, compared to a 19% prevalence of pes planus (flat feet). The aetiology of pes
cavus is not well understood but many cases are thought to be neurogenic in origin, the most common neuromuscular cause being Charcot–Marie–Tooth disease.\textsuperscript{219}

Management of pes cavus in older people is based on addressing the presenting symptoms and associated complaints (such as plantar lesions) using conservative techniques, rather than ‘correcting’ the structural anomaly itself. A recent randomised trial indicated that customised foot orthoses are effective in redistributing pressures away from the forefoot and heel, thereby reducing symptoms associated with painful pes cavus.\textsuperscript{220} Inadequate shock attenuation associated with pes cavus may also be addressed by the provision of footwear with ethyl vinyl acetate midsoles\textsuperscript{221,222} or by the addition of a shock-absorbing cushioned heel shoe modification (Ch. 12).

\section{TARSAL TUNNEL SYNDROME}

First described in 1960,\textsuperscript{223} tarsal tunnel syndrome is an uncommon entrapment neuropathy caused by compression of the posterior tibial nerve (or its branches) beneath the flexor retinaculum. The condition is characterised by anaesthesia, paraesthesia and burning pain in the medial malleolar region that radiates along the course of the calcaneal, medial plantar or lateral plantar nerves. Tarsal tunnel syndrome may develop secondary to direct trauma of the posterior tibial nerve, the development of space-occupying lesions such as ganglia, rapid weight gain or inflammatory conditions such as rheumatoid arthritis.\textsuperscript{224,225}

The diagnosis of tarsal tunnel syndrome is based on patient history and physical examination. Symptoms are generally exacerbated by prolonged periods of weightbearing activity and can be elicited by pronating the foot and dorsiflexing the toes or by direct percussion of the nerve (referred to as a positive Tinel’s sign\textsuperscript{226}). Electrophysical studies are considered to be the gold standard diagnostic test for tarsal tunnel syndrome and will reveal reduced sensory nerve conduction velocity and increased latency of motor nerves compared to the unaffected side.\textsuperscript{227} Magnetic resonance imaging is not commonly used but may be useful for identifying space-occupying lesions exerting pressure on the neurovascular bundle.\textsuperscript{228}

Treatment of tarsal tunnel syndrome is largely empirical, as few rigorous intervention studies have been undertaken. Conservative treatment options include NSAIDs, corticosteroid injection and orthoses to control excessive foot pronation.\textsuperscript{224,225} Surgical management of tarsal tunnel syndrome includes decompression of the nerve by flexor retinaculum release and, if necessary, neuroma excision. Reported outcomes from case series studies are only moderate, with 17–43\% of patients reporting dissatisfaction with the result.\textsuperscript{229–231}

\section{SINUS Tarsi SYNDROME}

The sinus tarsi is a conical cavity that acts as a boundary between the anterosuperior surface of the calcaneus and the inferior aspect of the neck of the talus, and contains a fat plug, joint capsule, neurovascular elements and five ligaments. In 1958, O’Connor\textsuperscript{232} described a condition characterised by persistent lateral ankle pain following an inversion sprain, which was attributed to scarring of the ligaments within the sinus tarsi. Since this initial report, several authors have described a similar syndrome, which has been variously attributed to synovitis, entrapment of the superficial peroneal nerve, ganglia, ligament damage and tarsal coalition.\textsuperscript{233–235}

The classical clinical presentation of sinus tarsi syndrome is that of persistent lateral ankle pain and instability in patients with a history of recurrent ankle sprains; however, the condition may occur in the absence of previous trauma.\textsuperscript{233,235} Of particular interest in older patients, cases of sinus tarsi syndrome associated with gout affecting the subtalar joint have been reported.\textsuperscript{236} Pain can be elicited on direct palpation and by supinating the subtalar joint. Plain film X-ray is rarely helpful in reaching a diagnosis and, although MRI may reveal ligament tears and signs of fibrosis, whether these observations are highly characteristic of the condition is yet to be fully determined.\textsuperscript{236}

As with tarsal tunnel syndrome, treatment of sinus tarsi syndrome is largely empirical. No trials of conservative treatments have been undertaken, with only a single case study reporting good results with the use of foot orthoses.\textsuperscript{237} A recent case series of 13 patients who underwent resection of the deep peroneal nerve reported highly favourable results, with 10 patients reporting complete pain relief after 6 months.\textsuperscript{238}

\section{SUMMARY}

A wide range of pathological conditions may manifest as pain in the rearfoot in older people and it is clear...
that our understanding of the pathophysiology of many of these conditions is currently quite limited. Subsequently, treatment of rearfoot problems can be challenging. Because of the higher rate of complications and prolonged recovery times associated with rearfoot surgery in older people, conservative interventions should be tried before considering surgical intervention.

References

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Orthotic therapy plays a major role in the conservative management of foot disorders in older people. In the UK National Health Service, it has been estimated that £38 million is spent on orthoses each year, with foot orthoses accounting for 75% of a district hospital’s total appliances budget. Orthotic devices range from simple adhesive pads that can be manufactured during a routine consultation through to more complex techniques involving the construction of custom-moulded insoles derived from plaster casts of the patient’s feet.

The basic principles of orthotic therapy are to reduce the magnitude of pressure applied to painful regions of the foot, to realign structures within the foot to correct any existing deformity, and to control motion of joints in the foot, either by restricting excessive motion or by facilitating joints with limited motion. Although these underlying principles are generally agreed upon, there are several opposing theories pertaining to the biomechanical function of the foot, which give rise to a plethora of alternative orthotic prescription protocols to achieve these objectives. It is beyond the scope of this chapter to discuss these issues in detail. Therefore, it is recommended that the reader refer to several recent reviews on the topic and supplement the information contained in this chapter with textbooks specifically focused on foot orthoses, such as Foot Orthoses and Other Forms of Conservative Footcare and Clinical Biomechanics of the Lower Extremities.

The classification and nomenclature of foot orthoses is also a somewhat vexed issue, as no widely agreed upon system has yet been adopted. For the purpose of this chapter, the following classifications are used:
Chairside orthoses: padding techniques that can be manufactured during a routine consultation from widely available materials such as felt, foam and silicone putty

Non-cast insoles: orthoses placed inside the shoe that do not require a cast to be taken of the patient’s foot

Prefabricated orthoses: mass-produced commercially available devices that can be purchased from orthotic laboratories, medical suppliers or pharmacists

Cast orthoses: devices manufactured from soft or rigid materials using a plaster replica of the patient’s foot

Ankle–foot orthoses: prefabricated or customised devices that extend above the ankle joint.

Orthotic prescription and manufacture for older people is essentially the same as for younger people; however, several factors require additional consideration. Firstly, given the high prevalence of ill-fitting footwear in older people,11 particular care needs to be taken to ensure that the patient’s footwear is appropriate for orthotic therapy, particularly with regard to the depth of the toebox. Secondly, the mobility of older patients should be evaluated to ascertain their ability to reach their feet, as orthoses fitted directly to the foot will need to be removed and replaced before and after bathing and sleeping. Finally, it is essential to assess an older person’s skin integrity prior to prescribing orthoses and, where there is some risk of skin damage, orthoses should be covered with a soft and compliant material and carefully checked for rough or sharp edges on a regular basis.

The following chapter briefly outlines the use of each of these types of orthosis in the management of foot disorders in older people. The broader applications of foot orthoses in this age-group, such as the role of orthoses in the management of knee osteoarthritis and in improving balance, are also discussed.

CHAIRSIDE ORTHOSES

The term chairside orthoses refers to simple devices that can be quickly and easily manufactured during a routine patient consultation. The most common material used for these devices is adhesive semicompressed felt, which is available in several thicknesses (most commonly 2 mm, 5 mm, 7 mm and 10 mm).

Various types of foam can also be used. As a general rule, semicompressed felt is more effective in pressure redistribution, whereas foam is more effective in shock absorption and tends to last longer. Chairside orthoses can be directly adhered to the foot and secured with tape, fixed inside the shoe or made into replaceable devices. These devices will invariably become less effective over time, as a result of material compression and/or loss of adhesion, and will therefore need to be replaced regularly. In most cases, chairside devices are designed to provide short-term symptomatic relief and, if effective, to help guide the selection and construction of more permanent devices. The following section briefly describes some of the more commonly used chairside orthoses and their clinical applications. Additional variants of these basic pad designs can be found in Paddings and Strappings of the Foot12 and Practical Orthotics for Chiropodists.13

HORSESHOE PAD

As the name suggests, the horseshoe pad (Fig. 11.1A) is a U-shaped pad with two arms that extend onto the dorsum of the proximal phalanges of the toes. This pad is used to deflect pressure away from dorsal lesions on the proximal interphalangeal joints of hammer toes or claw toes, and is generally constructed from 7 mm compressed felt. The horseshoe pad is particularly effective at redistributing pressure away from a single lesion (in the example provided, the third toe) where the adjacent toes are neutrally aligned. For multiple lesions on adjacent toes, the crescent pad is generally used.

CRESCE­NT PAD

The crescent pad (Fig. 11.1B), also referred to as a U-pad, is used to deflect pressure away from dorsal lesions affecting one or more of the proximal interphalangeal joints. Depending on the severity of the lesser toe deformity, 5 or 7 mm felt can be used to ‘fill in’ the space between the dorsal aspect of the metatarsal heads and the proximal interphalangeal joints. For optimum results, the distal edge of the pad should closely follow the shape of the dorsal prominences and be bevelled on the inferior surface to improve the fit of the device.

Both the horseshoe and crescent pads can be directly adhered to the foot; however, for longer-term results, replaceable devices can be constructed by
placing the non-adhesive side to the foot, looping elastic strap around the toes and affixing the strap to the dorsal adhesive side, and covering the dorsal surface of the pad with tape (Fig. 11.2).

### TOE PROP

The toe prop, also referred to as a buttress appliance or crest pad (Fig. 11.1C), has several variations and functions. The aim of the basic plantar toe prop is to fill in the space between the plantar metatarsal heads and the apices of the toes, thereby redistributing load from plantar apical lesions, particularly in the presence of rigid claw toes. However, if the claw toe deformity is flexible, the distal edge of the pad can be extended further distally to assist in dorsiflexing the distal interphalangeal joint, thereby straightening the toes. A further variation (referred to as a dorsoplanter prop) involves the addition of a dorsal prop connected to the plantar prop by elastic strapping, which is thought to assist in straightening the toes by the shoe exerting a plantarly directed force on the dorsal pad while the plantar pad exerts a dorsally directed force, thereby plantarflexing the metatarsophalangeal joints and dorsiflexing the proximal and distal interphalangeal joints simultaneously.

### INTERDIGITAL WEDGE

The interdigital wedge or dumbbell pad (Fig. 11.1D) is used to assist in the separation of adjacent toes and is most commonly used in the short-term management of interdigital corns (both heloma dura and heloma molle). This pad is also used in the conservative management of onychocryptosis, as a means of
alleviating pressure from adjacent nail sulci. As the name suggests, the pad is cut into a dumbbell shape from compressed felt, placed between the toes and adhered directly to the dorsal and plantar surfaces of the foot. It is important to ensure that the thickness of the plantar aspect of the pad is reduced so as not to interfere with normal weightbearing. An alternative approach is to simply adhere a piece of felt to the medial or lateral aspect of the proximal phalanx; however, such devices tend to break down more quickly and, because of interdigital maceration, are difficult to get to adhere for long periods of time. Interdigital wedges may also be manufactured from silicone and, because of their close moulding to the space between the toes, tend to be more effective and last longer than felt pads (see later section on silicone devices).

**SADDLE PAD**

The saddle pad, also known as a *tendon pad* (Fig. 11.1E), is designed to alleviate dorsal pressure from footwear in the presence of prominent long extensor tendons. As the name suggests, the pad is directly adhered to the dorsum of the foot like a saddle, with a plantar groove cut into the pad to accommodate the tendon. In patients with several prominent extensor tendons (such as those with multiple clawtoes, hammertoes or retracted toes associated with pes cavus foot deformity), the saddle pad can be extended across the entire dorsal aspect of the foot (with multiple grooves for each tendon) and bevelled to ensure close apposition with the dorsal aspects of the metatarsal shafts.

**FOAM SLEEVES**

Prefabricated tubefoam has several uses. The simplest application of tubefoam is the construction of basic toe sleeves (Fig. 11.1F) for cushioning dorsal lesions, used with or without additional felt crescents. Larger diameter tubefoam can also be used in management of painful hallux valgus (by constructing a toe sleeve with a longer medial flange to place over the inflamed medial exostosis), or as removable alternative to the saddle pad, by placing the sleeve over one of the toes and extending a flange over the dorsum of the foot. Care needs to be taken; however, that the diameter of tubefoam selected is sufficient to prevent constriction of blood flow to the digits, particularly in older people with peripheral vascular disease.

**PLANTAR COVER**

The plantar cover, or *plantar pad*, extends from the stylloid process of the fifth metatarsal to the distal aspect of the metatarsal heads and covers the entire plantar metatarsal area (Fig. 11.3A). It can be manufactured from foam or felt of various thickness depending on the space available in the shoe. The distal edge of the pad is bevelled to improve comfort and adhesion. The plantar cover is used to cushion the metatarsal heads and is particularly useful in older people with atrophy of the plantar soft tissues. The pad can be directly adhered to the plantar surface of the foot, adhered to the inner sole of the shoe or made into a replaceable device by looping elastic strapping around the middle three toes, adhering the strap to the plantarly directed adhesive surface, and covering the plantar surface of the pad with tape.

The plantar cover can be modified to redistribute pressure from individual metatarsal heads by the addition of a ‘U’ (for the second, third or fourth metatarsal heads) or a ‘wing’ (for the first and/or fifth metatarsal heads), as shown in Figure 11.3B and C. Such pads are used to reduce loading on metatarsal heads affected by keratotic lesions and insufficiency fractures and have also been demonstrated to assist in the healing of plantar neuropathic ulcers in people with diabetes. The relative efficacy of ‘U’-shaped plantar covers compared to other devices for offloading the metatarsal heads, however, is unclear. A recent study using an in-shoe pressure analysis system indicated that a plantar metatarsal pad (discussed below) was more effective in reducing pressures.

**PLANTAR METATARSAL PAD**

The plantar metatarsal pad, also referred to as a *metatarsal pad*, has several variants. The most commonly described pad covers the shafts of the second, third and fourth metatarsals and follows the distal curve of the respective metatarsal heads (Fig. 11.3D). The pad is thought to have several functions:

- To redistribute load from the metatarsal heads to the shafts
- To redistribute load to the first and fifth metatarsal heads
- To straighten the central three toes.

Clinical indications for the use of this pad include keratotic lesions under the central metatarsal heads, flexible hammertoe deformity, interdigital neuroma and predislocation syndrome. Variants of the plantar
Chairside orthoses

Chairside orthoses

The optimum placement of the plantar metatarsal pad to reduce pressures under the metatarsal heads is unclear, as several studies have been undertaken with variable results. Six studies have found that a pad placed proximal to the metatarsal heads significantly reduces metatarsal head pressures (by up to 60%),21-26 two studies found no significant reduction in pressures with proximally placed pads27,28 and one study29 found that placing a pad 5 mm distal to the metatarsal heads reduced pressure more effectively than placing it 5 mm proximal to the metatarsal head. These variable findings are likely to reflect differences in plantar pressure measurement protocols and participant characteristics; however, it is also likely that the optimum location of plantar metatarsal pads requires some degree of trial and error. The clinical use of plantar pressure systems is ideal for this purpose. However, in the absence of such systems, some insight can be gained from subjective responses from the patient, as two studies have indicated that reported pain relief is significantly correlated with the degree of pressure reduction.22,24

**METATARSAL SHAFT PAD**

The metatarsal shaft pad, also known as an under pad,12 covers the plantar surface of one or more metatarsals (Fig. 11.3E). The aim of this pad is to elevate the metatarsal relative to adjacent metatarsals, and is thought to be of particular benefit in the management of intermetatarsal neuroma (in the case of a neuroma in the third–fourth intermetatarsal space, the pad is placed under the fourth and fifth metatarsal heads).30 Multiple shaft pads can also be placed to ‘rebalance’ pressure distribution across the plantar surface. Such devices, sometimes referred to as a forefoot imbalance pads31 or parallel strip padding,12 are considered to be of benefit in the management of plantar lesions caused by highly prominent (‘depressed’) central metatarsal

![Figure 11.3](image-url) Plantar padding techniques. A. Plantar cover. B. ‘U’ed plantar cover. C. Winged plantar cover. D. Plantar metatarsal pad. E. Metatarsal shaft pad. F. Extended shaft pad. G. Valgus pad. H. Plantar calcaneal pad.
heads, as may develop in conjunction with lesser toe deformity in the rheumatoid foot. In this case, two pads are applied to the first and fifth metatarsal shafts.

A variation of the shaft pad is the extended shaft pad (also known as Morton’s extension), which is placed under the first metatarsal but extends distally to completely cover the first metatarsophalangeal joint (Fig. 11.3F). This pad was originally designed to compensate for the so-called Morton’s foot type, characterised by an excessively short first metatarsal with subsequent overloading of the second metatarsal head. However, it is now recognised that such a foot type is far less common than originally thought and is not frequently associated with pathology. Nevertheless, this pad is useful for redistributing pressure away from the first interphalangeal joint in people with limited motion at the first metatarsophalangeal joint (such as people with hallux limitus/rigidus or limited joint mobility associated with diabetes).

**VALGUS PAD**

The valgus pad, also known as a scaphoid pad or long arch pad, fills in the medial longitudinal arch region of the foot (Fig. 11.3G). The aim of this pad is to support the medial arch and it has been shown that, when valgus pads are worn, plantar pressures increase under the lateral border of the foot, which may indicate a lateral shift in the centre of pressure associated with a reduction in foot pronation. Valgus pads are particularly useful as an adjunct in the management of forefoot ulceration in diabetic patients by ‘filling in’ the space between the heel and the forefoot, and are often used in conjunction with plantar footpad padding. A recent study of 30 diabetic patients by Guldemond et al reported that the addition of a valgus pad to a contoured foot bed with a metatarsal dome increased the degree of forefoot pressure reduction by up to 25%.

**PLANTAR CALCANEAL PAD**

The plantar calcaneal pad, or heel pad, is placed over the weightbearing surface area of the heel (Fig. 11.3H) and is used to reduce loading of the heel in patients with plantar heel pain syndrome (including plantar calcaneal bursitis and calcaneal stress fractures). The efficacy of plantar calcaneal pads has not been examined in detail; however, there is some suggestion that rigid heel cups may be more effective in older people, as they contain the lateral expansion of the heel on weightbearing, thereby improving shock attenuation by maintaining the vertical thickness of the heel pad. The manufacture of felt or foam chairside devices for the heel has been largely supplanted by the availability of prefabricated heel pads manufactured from viscoelastic materials (see below).

**RETROCALCANEAL PAD**

The retrocalcaneal pad, also known as a posterior heel pad, is a circular pad placed on the posterior aspect of the heel to reduce friction from footwear in patients with retrocalcaneal bursitis or Haglund’s deformity. Depending on the size of the bony prominence, an aperture may also be cut into the pad. As with plantar calcaneal pads, the availability of prefabricated, adhesive viscoelastic materials has largely replaced the traditional felt or foam pads, as they are more effective at reducing friction and tend to last much longer.

**SILICONE ORTHODIGITA**

The availability of medical grade silicone putties, originally developed for dental casting applications, has enabled the manufacture of long-lasting, washable, customised orthoses within the time constraints of a routine clinical consultation. Commercially available two-part systems consisting of the silicone putty and a catalyst (such as Otoform K® and Podiform®) can be used to manufacture a wide range of devices, including toe props, interdigital wedges and bunion shields (Fig. 11.4). Silicone orthoses are particularly useful for reducing pressures under the apices of the toes. A recent study of 14 patients with diabetes indicated that custom-moulded silicone toe props reduced digital plantar pressures by 30% and, when used in conjunction with keratotic lesion debridement, pressures were reduced by 54%. In addition to reducing toe pressures, there is some evidence that flexible lesser toe deformities can be gradually ‘corrected’ using serial toe props, with each new device shaped to provide slightly more correction than the previous one.

**NON-CAST INSOLES**

As the name suggests, non-cast insoles are customised orthotic devices that do not require a cast to be taken of the patient’s foot. Traditionally, these devices were
manufactured by affixing various types of rubber or foam pads (using similar designs to the chairside devices previously discussed) to a flat insole made from compressed cardboard, cork, leather or a combination of all three materials. The main advantages of non-cast insoles over chairside devices is that they do not have to be affixed directly to the foot and, because of the much greater resilience of the materials used, they have a much longer lifespan. The main disadvantage of non-cast insoles is that the insole base is constructed to match the shape and size of the last of the shoe and, as such, cannot always be transferred from one pair of shoes to another.

The technique involves obtaining an accurate tracing of the insole of the patient’s shoe by trimming a piece of cardboard and fitting it inside the shoe, then recording the location of key anatomical features of the foot (particularly the metatarsal heads and the location of plantar lesions). The pad design is then marked on to the cardboard template, and constructed from the appropriate materials (generally open cell black rubber). The pad is then adhered to a compressed cardboard base and covered with a soft material such as chamois. The addition of simple wedges to non-cast insoles in an attempt to support forefoot deformities (e.g. forefoot varus and valgus) and to control foot pronation has also been suggested. However, while such an approach may be a useful temporary measure to ascertain the potential effectiveness of a more ‘functional’ foot orthosis, it has recently been shown that such devices have relatively minor effects on foot kinetics and kinematics, possibly because of the lack of medial longitudinal arch support.

To a large extent, the wide availability and low cost of prefabricated orthoses has made the traditional manufacture of non-cast insoles redundant. In contemporary clinical practice, many foot specialists will simply modify a prefabricated orthosis by adhering appropriate padding designs to the orthosis shell itself. This approach provides the additional benefits of customised forefoot padding designs to the contoured arch and heel cup of the prefabricated orthosis, and is much less time-consuming.

**PREFABRICATED ORTHOSES**

**SILICONE AND OTHER VISCOELASTIC DEVICES**

A wide range of silicone appliances are now commercially available from medical suppliers and pharmacists (Fig. 11.5). To some extent, these devices are replacing the chairside manufacture of felt and foam pads for minor foot complaints. Although over-the-counter silicone appliances are considerably more expensive than chairside devices, the viscoelastic properties of the silicone make them very comfortable and surprisingly long-lasting. Some silicone devices are also impregnated with mineral oil, which may have additional effect of hydrating keratotic lesions. The key disadvantage of these appliances is that they are difficult to customise.

Few studies have been undertaken to assess the efficacy of prefabricated silicone appliances. Claissé et al have shown that a commercially available silicone toe prop significantly reduces pressures under the...
apices of the second and third toes and under the third and fourth metatarsal heads. Caselli et al.\(^4\) compared a full length silicone insole (Viscoped\(^5\)) versus a simple insole made from Poron\(^\circledR\) in 35 patients with plantar keratotic lesions and reported no significant differences between the groups in relation to pain reduction. Finally, Kelly & Winson\(^4\) compared the efficacy of a full-length silicone insole with extra soft silicone inserts under the metatarsal heads (Viscoped\(^5\)) versus a Plastazote\(^\circledR\) customisable insert system (Langer Blueline\(^\circledR\)) in 33 patients with lesser metatarsalgia, and found that the Langer device provided greater pressure reduction and pain relief. Although further research needs to be undertaken to more thoroughly assess the efficacy of silicone devices, the latter two studies highlight that the use of more high-tech materials does not necessarily produce better outcomes, and that customisation may be beneficial in certain cases.

**HALLUX VALGUS SPLINTS**

The use of splints to realign the hallux in people with hallux valgus deformity has been described by several authors,\(^5\) and a range of splints are now commercially available (Fig. 11.6). These devices are worn when sleeping and are designed to hold the hallux in a rectus position in an attempt to reduce the contracture of soft tissues pulling the hallux in an abducted position. Only two studies have been undertaken to assess the efficacy of this approach. Groiso\(^5\) conducted a case series study of 56 children and adolescents with juvenile hallux valgus who received thermoplastic splints and exercises, and reported that the hallux abductus angle and intermetatarsal angle had reduced in half the group 2–6 years later. In contrast, Juriansz\(^5\) compared a hallux valgus night splint to no treatment in 28 people ranging in age from 10 to 77 years and found no improvement in clinically determined degree of deformity.

Clearly, further research is required to fully ascertain the effectiveness of splints in the management of hallux valgus in older people; however, it is likely that splints would only be effective in milder forms of the condition where no significant bony remodelling has taken place. Furthermore, the acceptability of night splints in older patients is uncertain. Given that sleep disturbances are common in older people\(^5\) and that high levels of dissatisfaction have been reported with plantar fasciitis night splints because of sleeping difficulties,\(^5\) it is likely that hallux valgus night splints would be poorly tolerated in many older people.

**CONTOURED INSOLES**

A plethora of prefabricated foot orthoses have become available in recent years, not only from medical suppliers and pharmacists but also from custom orthotic laboratories. These devices are manufactured from a
wide range of materials (including polypropylene, polyethylene, ethyl vinyl acetate and carbon fibre) and can vary considerably in relation to length (three-quarters or full length), arch height, flexibility, weight, longevity and cost (Fig. 11.7). Some prefabricated orthoses are heat-mouldable, whereas others are available in modular form, with a range of additions (including frontal plane wedges, metatarsal pads, etc) that can be used to customise the device (Fig. 11.8). Whether structural variations in prefabricated orthoses have a significant influence on foot function or clinical outcomes has not been explored in detail; however, preliminary studies indicate that differences exist between devices in relation to the position adopted by the foot in static stance. Selecting which prefabricated orthosis to use is by no means a scientific process; rather, such choices are made on the basis of availability, cost and individual clinician preference.

As stated previously, the wide availability of contoured prefabricated orthoses has largely replaced the manufacture of non-cast insoles. However, prefabricated orthoses appear to have had less impact on the prescription and manufacture of cast orthoses. Indeed, a recent survey of prescribing habits of podiatrists in Australia and New Zealand indicated that the most frequently prescribed orthosis was a cast orthosis (72% of participants compared to only 12% for prefabricated orthoses).\textsuperscript{55} One of the fundamental research questions that needs to be addressed in relation to prefabricated foot orthoses is whether they are as effective as the more time-consuming (and expensive) cast orthoses. A recent audit of 139 patients in the UK suggested that prefabricated orthoses provided similar levels of patient satisfaction to cast devices.\textsuperscript{5} However, the only condition for which high-quality comparisons have been undertaken is heel pain. A recent randomised controlled trial by Landorf et al\textsuperscript{56} found that, although both cast and prefabricated orthoses reduced plantar heel pain to a similar degree at 3 months, no significant differences between the groups were noted at 12 months. This paper also included a meta-analysis of their results combined with those of the earlier studies,\textsuperscript{57–59} which indicated no significant benefit of cast orthoses over prefabricated orthoses. These findings suggest that prefabricated orthoses may have similar efficacy to customised orthoses, at far less cost, for the management of heel pain.

CAST ORTHOSES

Cast orthoses, also referred to as functional orthoses, are devices manufactured from an impression of the patient’s foot. Most commonly, cast orthoses are constructed from rigid thermoplastics that are heat-moulded over a positive plaster cast, with the aim of providing a precise fit of the device to the plantar contours of the foot (Fig. 11.9). By modifying both the positive cast and the orthotic shell itself, the clinician can theoretically modify a wide range of aspects of the weightbearing function of the foot. More recently, alternative impression techniques (such as optical scanning) and manufacturing methods (using CAD-CAM technology) have become available,
Although these systems are yet to have a widespread impact on traditional manufacturing practices.

Because of our relatively limited understanding of the biomechanical function of the foot and the wide range of modifications that can be made to the shape of an orthosis, there is currently no consensus as to how cast orthoses should be prescribed and manufactured. Indeed, there is virtually no agreement as to how the foot should be assessed, how the cast should be taken (i.e. prone or supine neutral plaster casting, partially weightbearing foam box casting or optical scanning), the materials that should be used or the indications for orthotic shell variations (plantar fascial grooves, heel posts, cut-outs, apertures, etc). Subsequently, in clinical practice, prescription of cast orthoses is more an art than a science and the outcomes of orthotic therapy may to some extent be influenced by clinical expertise and experience.

Nevertheless, several studies have shown that cast orthoses do indeed modify selected aspects of foot function (including plantar pressure distribution, joint kinematics and muscle activity) and randomised controlled trials have reported significant improvements in pain and function in people with rheumatoid arthritis, heel pain and painful pes cavus. There is also some preliminary evidence that cast orthoses may be more effective in managing symptoms associated with foot osteoarthritis than nonsteroidal anti-inflammatory medications.

Although these findings are generally positive, as stated previously there is a need for further studies to fully ascertain the benefits of cast orthoses over prefabricated orthoses.

As stated in the introduction, it is beyond the scope of this chapter to discuss the details of prescription and manufacture of cast orthoses. Therefore, the reader is referred to specialists texts such as The Functional Foot Orthosis, Foot Orthoses and Other Forms of Conservative Footcare and Clinical Biomechanics of the Lower Extremities, as the approaches outlined in these texts are equally applicable to older people. However, it is worth mentioning that many clinicians are somewhat reluctant to prescribe cast orthoses for older people, on the assumption that they may not be able to tolerate rigid materials. While it is certainly true that older people with severe circulatory disorders and poor skin integrity may not be ideal candidates for rigid foot orthoses because of the risk of skin damage, there is no evidence that older people in general have any greater difficulty adjusting to cast orthoses than their younger counterparts. Indeed, because of age-related arch lowering and the increased prevalence of foot deformity associated with advancing age, it could be argued that older people have a greater need for accurate customisation, as they may have difficulty finding a prefabricated device to match the contour of their foot.

**ANKLE–FOOT ORTHOSES**

Ankle–foot orthoses (AFOs) are widely used in the management of conditions resulting in weakness of the ankle dorsiflexors (such as poliomyelitis, cerebral palsy and cerebrovascular accident) in an attempt to prevent foot drop during the swing phase of gait.
Conventional AFOs consisting of a simple metal caliper attached to bespoke footwear have been largely replaced by thermoplastic AFOs manufactured from plaster casts. Although more difficult to manufacture, thermoplastic AFOs provide more precise control of the ankle and are aesthetically more pleasing to the patient (Fig. 11.10). Several studies have demonstrated that AFOs produce significant improvements in temporospatial gait parameters, energy efficiency and lower limb muscle activity in hemiparetic patients \(^74\)–\(^77\) and are generally well tolerated. \(^78\)

More recently, several types of AFO have been recommended for use in the conservative management of degenerative osteoarthritis of the subtalar and ankle joints \(^79\) and tibialis posterior dysfunction. \(^80\),\(^81\) The underlying premise of this approach is that excessive motion of the rearfoot complex is responsible for the symptoms associated with these conditions and that conventional foot orthoses are inadequate for controlling the pronatory motion in severe flat foot deformity. Gait analysis studies indicate that AFOs do indeed alter the motion of the rearfoot complex; however, different AFO designs have different effects. Kitaoka et al.\(^82\) compared a rigid thermoplastic AFO, a rigid hindfoot orthosis (HFO-R: similar to the AFO but trimmed to extend only as far distally as the weightbearing surface of the heel and as proximal as the mid-calf region) and an articulated hindfoot orthosis (HFO-A: similar to the AFO but trimmed to the mid-calf region and with the addition of a sagittal plane hinge). The greatest reduction in rearfoot motion was achieved with the AFO; however, this device also resulted in the adoption of a less propulsive gait pattern. On the basis of this observation, the authors suggested that the HFO-R and HFO-A may provide the best balance between motion restriction and allowing sufficient propulsion for normal gait. Subsequent studies in patients with subtalar\(^83\) and ankle\(^84\) osteoarthritis confirmed that both the HFO-R and HFO-A were effective in reducing rearfoot motion on a range of surfaces; however, the HFO-R provided optimum results.

Although no studies have directly evaluated the biomechanical effects of AFOs in patients with tibialis posterior dysfunction, two case series investigations have reported favourable results with AFOs or a combination of AFOs and other conservative treatments. Chao et al.\(^81\) reported significant improvements in pain and function in 49 patients treated with AFOs or foot orthoses over an average 15-month period. Similarly, in 47 patients with early stage tibialis posterior dysfunction, Alvarez et al.\(^85\) reported that 83% of patients improved following a treatment regimen of calf stretching and strengthening and foot orthoses or AFOs.

**FOOT ORTHOSES AND KNEE OSTEOARTHRITIS**

Osteoarthritis of the knee is one of the most common chronic musculoskeletal disorders associated with ageing, affecting approximately 20–40% of people older than 65 years. \(^86\) Although all three compartments of the knee may be affected, medial compartment involvement is the most common, because of the large compressive forces generated when walking. \(^87\) It has previously been demonstrated that contact forces within the knee when walking are considerably greater in the medial compartment than in the lateral compartment and that varus alignment of the knee joint is strongly associated with progression of medial compartment osteoarthritis. \(^88\)

In response to these findings, several studies have been undertaken to investigate the efficacy of different forms of lateral wedging as a conservative treatment for medial compartment knee osteoarthritis, based on the hypothesis that decreasing the varus moment at the knee may alleviate compressive forces in the medial compartment. \(^89\)–\(^92\) The first study by Sasaki & Yasuda\(^89\) found that patients wearing a laterally wedged insole (manufactured from either sponge...
rubber or leather) in conjunction with taking non-steroidal anti-inflammatory drugs (NSAIDs) reported greater reductions in pain than patients prescribed NSAIDs alone. Subsequent uncontrolled studies have reported similar findings. Wolfe & Brueckmann\(^9\) reported that 82% of patients with medial knee osteoarthritis reported decreased pain while wearing a lateral heel wedge. Tohyama et al\(^9\) found that lateral heels reduced knee pain in patients with early medial compartment osteoarthritis. Keating et al\(^9\) reported that 32 out of 85 patients with medial knee osteoarthritis reported ‘excellent’ improvement in pain scores while wearing a lateral heel wedge, and Rubin & Menz\(^9\) reported significant reductions in knee pain in 30 osteoarthritis patients using laterally wedged custom foot orthoses. The only randomised comparisons so far undertaken reported that a laterally wedged insole combined with subtalar joint strapping was more effective in reducing knee pain than a medial compartment orthoses. The only randomised comparisons so far undertaken reported that a laterally wedged insole combined with subtalar joint strapping was more effective in reducing knee pain than a wedge placed in a sock-type ankle support.\(^9\) More recently, the first randomised controlled trial reported that, while no symptomatic or functional improvement was noted in subjects prescribed laterally wedged cork and rubber insoles, they required less NSAIDs for pain management than the control group.\(^9\) Although these preliminary results are promising, recent systematic reviews have concluded that there is currently insufficient high-quality evidence to support the long-term use of laterally wedged orthoses as, despite some evidence of temporary pain relief, such devices do not appear to alter the normal course of knee osteoarthritis or have any impact on radiological severity. Nevertheless, there may be some value in trying wedged insoles for short-term pain relief in older people who are considering knee replacement surgery.

FOOT ORTHOSES AS A BALANCE AID

Sensory receptors on the sole of the foot play an important role in maintaining balance by providing the brain with information about foot position and changes in plantar pressure distribution. This is evidenced by numerous studies that have demonstrated balance deficits in subjects with sensory neuropathy.\(^10\) In response to these observations, there have been several studies undertaken recently to determine whether the sensory role of plantar mechanoreceptors can be harnessed to develop novel interventions to improve balance in older people.\(^10\) Theoretically, placing textured insoles under the foot may provide additional tactile sensory input that can be used by the brain to compensate for deficits in other systems contributing to balance.

While a number of studies have indicated that different types of foot orthoses may improve balance, the mechanisms that may be responsible for this have only recently been investigated. Hosoda et al\(^10\) compared responses to platform perturbation in healthy subjects when wearing two types of footwear (flat, leather-soled sandals and ‘health sandals’ containing an insole with numerous small raised projections), and reported shorter reflex latencies when the health sandals were worn. Similarly, Waddington & Adams\(^10\) evaluated the effect of textured rubber insoles (7 mm deep nodules at a density of 4/cm\(^2\)) on the ability of healthy young subjects to detect ankle inversion, and found that inserting an insole into the shoe provided similar movement detection to the barefoot condition. The authors concluded that textured insoles may be able to compensate for the loss of sensitivity produced by wearing soft-soled footwear, presumably by enhancing sensory feedback. Maki et al\(^10\) measured responses to platform perturbation in young and older people with and without a specially designed plastic tube attached to the perimeter of the sole of the foot. This ‘plantar facilitation’ reduced the incidence of multiple stepping responses when the platform was displaced in the anteroposterior direction, suggesting that the enhanced sensory input provided by the insoles during the initial protective step response was used by the brain to stabilise posture, rendering an additional step unnecessary. More recently, Priplata et al\(^11\) demonstrated significant reductions in sway variables when older people stood on randomly vibrating insoles and suggested that the introduction of tactile ‘noise’ could ameliorate age-related impairments in balance control.

AFOs may also have positive effects on balance in older people with peripheral neuropathy. Richardson et al\(^11\) have recently demonstrated significant improvements in temporospatial gait regularity when older people with peripheral neuropathy walked on an irregular surface while wearing semi-rigid AFOs. This finding is consistent with previous laboratory studies, which indicated that tactile information derived from a stimulus above the ankle is used by the brain to control posture and may be able to at least partially compensate for loss of plantar sensation.\(^12,13\)

Although these results provide interesting insights into the role of peripheral sensory input on stabilisa-
tion of posture, a great deal more research is required before insoles can be considered an effective falls prevention strategy in older people. The issue of comfort may also be a practical constraint, as people with sensitive feet or those who suffer from foot pain may not welcome the additional stimulation provided by the orthoses.

**SUMMARY**

This chapter has provided a brief overview of the use of foot orthoses in the management of foot disorders in older people. Many foot problems can be successfully managed with the use of very simple pads manufactured from inexpensive materials, the design of which can be modified according to the needs of individual patients. The availability of over-the-counter silicone devices and prefabricated contoured orthoses has provided the clinician with a wide array of treatment options, and there is emerging evidence that foot orthoses may have a role in the management of knee osteoarthritis and in falls prevention. Provided that the patient has sufficient skin integrity and appropriate footwear, and is sufficiently mobile to be able to change or remove orthoses where necessary, the prescription and manufacture of foot orthoses for older people, including cast orthoses, is essentially no different from that of younger people and should always be considered as a conservative management strategy.

**References**


56. Landorf KB, Keenan AM, Herbert RD. Effectiveness of foot orthoses to treat plantar fasciitis: a randomized trial. Archives of Internal Medicine 2006; 166: 1305–1310.


Footwear plays an important role in protecting the foot from extremes of temperature, moisture and mechanical trauma. However, since the development and widespread popularity of fashion footwear in the 1600s, the functional aspect of footwear has largely been supplanted by the requirements of fashion. In both men and women of all ages, shoe selection is primarily based on aesthetic considerations, many of which are incompatible with the optimal function of the foot and ankle. In older people, inappropriate footwear often causes (or at least contributes to) foot pain and deformity and therefore it is essential that foot care specialists have a sound understanding of the effects of footwear on the older foot. The following chapter discusses the shoe-wearing habits of older people, the relationship between footwear and foot problems, and the use of footwear modification and prescription footwear as a therapeutic modality. Because of the high rate of accidental falls and fractures in older people, the effect of shoe design on balance is also discussed. Finally, issues related to compliance with footwear recommendations are reviewed.

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**SHOE-WEARING HABITS OF OLDER PEOPLE**

It has long been recognised that many older people wear inappropriate footwear (Fig. 12.1). A household survey of people aged over 80 years conducted in the UK found that most wore slippers all day, irrespective of whether or not they were housebound. Similarly, a survey of indoor shoe-wearing habits of...
128 older people in Australia indicated that more than half spent less than $30 Australian dollars on their indoor footwear (most commonly slippers), replaced them infrequently, and often wore their indoor shoes for outdoor activities. More recently, a survey of subacute aged care hospital patients reported that only 14% wore ‘safe’ footwear, with the most commonly observed detrimental features being a lack of fastening (86%), slippery soles (86%) and an excessively flexible heel counter (77%).

By far the most commonly encountered problem with footwear in older people is the wearing of shoes that are too small. Burns et al compared the length and width of the feet and shoes of 65 people aged between 64 and 93 years attending a rehabilitation ward and reported that 72% wore shoes of an incorrect size. Menz & Morris assessed length, width and total area of feet and footwear in 176 older people and reported that 81% wore indoor shoes narrower than their feet and 78% wore outdoor shoes narrower than their feet. Finally, a study of 440 veterans affairs patients in the USA reported that only 26% were found to be wearing appropriately sized shoes.

Several factors may be responsible for the high prevalence of ill-fitting footwear in older people. Firstly, fashion exerts a powerful influence over footwear selection, particularly in women, and it is clear that many people are willing to endure foot pain and deformity in order to conform to societal expectations of footwear aesthetics. Secondly, few older people regularly have their feet measured, as most assume that their shoe size remains constant throughout their adult life. Finally, it has been suggested that commercially available footwear simply does not adequately cater for the dimensions of the older foot. A recent study of 668 older people in Germany found that most older people have feet that are broader than currently available casual footwear, which goes some way to explaining the large number of older people who report difficulty in purchasing comfortable shoes.

**DETRIMENTAL EFFECTS OF FOOTWEAR**

It has long been suspected that the deformation of the foot caused by shoes is a major contributing factor to foot problems such as hallux valgus (bunions), lesser toe deformity, corns and calluses. Indirect evidence for the detrimental effects of footwear can be derived from reports of very low prevalence of foot problems in populations that have never worn shoes, and the marked increase in the number of surgical procedures performed for hallux valgus in Japan following the adoption of Westernised footwear in preference to the traditional sandal. A US survey of 356 women aged between 20 and 60 years revealed that 88% wore shoes that were narrower than their feet, and those with the greatest disparity between foot width and shoe width were more likely to suffer from foot pain.

Two recent studies have evaluated the association between footwear fitting characteristics and foot problems in older people. Burns et al compared the length and width of the feet and shoes of 65 people aged between 64 and 93 years attending a rehabilitation ward and reported that the wearing of shoes of incorrect length was significantly associated with the presence of foot ulceration and foot pain, which the authors attributed to excessive friction generated from the foot sliding inside the shoe. More recently, a study of 176 people aged over 65 years demonstrated that most participants wore shoes narrower than their feet, with women wearing shoes that were shorter, narrower and with a reduced total area compared to their feet than men. Wearing shoes substantially narrower than the foot was associated with corns on the toes, hallux valgus deformity and foot pain, whereas wearing shoes shorter than the foot was associated with lesser toe deformity.

Ill-fitting footwear is of particular concern for older people with diabetic peripheral neuropathy because of the risk of ulceration, infection and amputation.
Although ulceration and amputation are caused by a range of factors, poorly fitting footwear is thought to be a contributing factor in approximately 50% of cases. Indeed, a recent study of 256 veterans with diabetes indicated that those with foot ulceration were five times more likely to have poorly fitting footwear.

In addition to incorrectly fitting footwear, the wearing of shoes with elevated heels is thought to contribute to the development of foot problems by increasing the pressure borne by the metatarsal heads and by interfering with the normal function of the first metatarsophalangeal joint during gait. Only two studies have been undertaken to explore this relationship in older people. Dawson et al interviewed 127 women aged 50–70 years regarding the highest heels they had worn for various activities across 10-year age bands (20s to 50s), and found that the wearing of lower heels for some activities was associated with an increased likelihood of having foot arthritis, pain and hallux valgus. This counterintuitive result may have been due to recall bias, in that women with foot problems may have been more likely to underestimate past heel height use. Furthermore, establishing an association between current foot problems and history of wearing high heels is difficult, as most women in this age group have been exposed to this type of footwear. More recently, Menz & Morris reported that wearing shoes with heel elevation greater than 25 mm was associated with hallux valgus and plantar calluses in older women.

Healthcare costs associated with footwear-related foot problems in older people are considerable. Assuming that inappropriate footwear is responsible for, or at least contributes to, 75% of foot problems requiring surgical treatment, Coughlin & Thompson have estimated that, in the USA in 1991, 209 000 bunionectomies, 210 000 hammer toe corrections, 119 000 bunionette repairs and 66 500 neuroma resections were performed, at a cost of approximately US$3 billion. Although the 75% figure is probably an overestimate, these figures do not include the costs of conservative management of footwear-related foot problems, so the true figure is likely to be much higher.

Taken together, these studies generally support the widespread view that the use of inappropriate footwear is highly prevalent in older people and is associated with the development of foot problems. As such, advising older patients regarding more suitable footwear is an essential component of clinical management, and changing footwear may, in and of itself, lead to the resolution of many foot complaints. Strategies for advising patients to change their footwear are discussed later in this chapter.

**FOOTWEAR MODIFICATIONS**

Footwear modification (pedorthics) is a useful conservative management strategy for older people with foot problems. The aim of footwear modification is to reduce shock and shear, to relieve excessive pressure from sensitive or painful areas, to accommodate, correct and support deformities, and to control or limit painful motion of joints. This may be achieved by changing the geometry of the sole to influence weightbearing patterns and by modifying the shape of the upper to accommodate bony deformities. These approaches are particularly useful in the management of diabetic foot ulcers and chronic arthritic conditions such as rheumatoid arthritis and following surgical fusion of the tarsal joints. The following section briefly discusses the most common footwear modifications used in the management of foot problems in older people.

**SHOCK-ABSORBING CUSHIONED HEEL**

As the name suggests, shock-absorbing cushioned heels (SACHs) are a modification of the plantar aspect of the shoe heel to enhance shock attenuation. This can be achieved by simply removing a wedge-shaped piece of the heel and replacing it with a more compressible material. SACHs are indicated in the management of heel pain in older people with atrophic heel pads, or as an attempt to increase lower limb shock attenuation in patients with age-related or surgically induced limited joint range of motion (such as patients who have undergone triple arthrodesis). No studies have directly evaluated the biomechanical effects of SACHs, although several authors have demonstrated that shoes with softer soles reduce both the magnitude and velocity of accelerations transmitted through the lower limb at heel strike.

**THOMAS HEEL**

The Thomas heel, also referred to as an S-heel, is a shoe modification in which the distal edge of the heel is extended on the medial side to a point corresponding to the navicular tuberosity. The aim
of this addition is to provide additional support to the medial arch in patients with flat foot deformity. A variant of the Thomas heel, referred to as the Thomas wedge, is a wedge of material placed within the medial border of the heel in an attempt to more directly limit eversion of the subtalar joint. In contemporary clinical practice, Thomas heels are rarely used in isolation but they may have some value in enhancing the effect of foot orthoses in overweight patients.

Few studies have been undertaken to assess the biomechanical or clinical effects of the Thomas heel in detail; however, a small study by Arlen & Carville demonstrated that the frontal plane alignment of the calcaneus does shift in the direction of inversion when standing in shoes that have undergone this modification. Using an in-shoe plantar pressure system, Xu et al. demonstrated that the addition of a Thomas heel redirected the centre of pressure laterally, with a concomitant decrease in the magnitude of pressures under the medial forefoot. The application of a reverse Thomas heel (a modification in which the distal edge is extended to the lateral side of the foot) had the opposite effect.

## ROCKER SOLE

The underlying concept of the rocker sole, also known as a rocker bottom sole, is to limit motion at joints in the foot by providing a rigid convex platform over which the body pivots from heel strike to toe off. Rocker soles have two main indications: the reduction of forefoot plantar pressure in people with diabetes or rheumatoid arthritis and the restriction of foot motion in people with osteoarthritis or those who have undergone surgical fusion of one or more tarsal joints. Broadly speaking, there are three types of rocker soles: rearfoot rockers, forefoot rockers and combined rockers (Fig. 12.4); however, the size and placement of the fulcrum can be modified according to individual patient needs.

Several studies have shown that the addition of a rocker sole reduces forefoot plantar pressures by between 30% and 65%. The optimum location of the rocker sole for reducing metatarsal head pressures has been demonstrated to be 55–60% of shoe length, while for reducing toe pressures it is 65% of shoe length. However, individual responses to rocker soles can be highly variable and in some cases a rocker sole may increase pressure under the foot. For this reason, it has been suggested that, where possible, some form of plantar pressure measurement should be used when prescribing rocker soles.

In addition to reducing forefoot pressures, rocker sole shoes have several other effects on gait, including an increase in cadence, a decrease in step length, reduced sagittal plane forefoot motion and increased ankle plantarflexion, hip extension and knee flexion. While many of these alterations can be considered to be beneficial if the aim of treatment is to restrict motion within the foot, changes in pelvic motion observed with rocker soles have been suggested to be indicative of lateral instability, so some caution is required when prescribing rocker soles for older people with balance problems.

## HEEL AND SOLE RAISES

The addition of material to the heel and/or sole of the shoe has several clinical indications in the management of foot problems in older people. Firstly, heel and sole raises are frequently employed in the management of limb length discrepancy, in an attempt to level the pelvis and improve the symmetry of the gait pattern. The most common cause of limb length discrepancy in older people is hip replacement
surgery. A postoperative analysis of 150 total hip replacement procedures by Williamson & Reckling indicated that 144 resulted in limb lengthening on the operated side, with an average lengthening of 16 mm. Of those who experienced limb lengthening, almost one-third required heel lifts to address postoperative symptoms. Secondly, shoe raises may have a role in the rehabilitation of hemiparesis, in an attempt to facilitate weight shifting towards the affected limb. Two recent studies have shown that the addition of a full-length sole raise (up to 1 cm in thickness) to the unaffected limb resulted in improved weightbearing symmetry and postural control in stroke patients. Thirdly, heel lifts are commonly used in the management of retrocalcaneal problems in people with limited ankle dorsiflexion. Lee et al. have shown that there is a progressive decrease in gastrocnemius muscle activity as the heel is raised, which may have the effect of reducing strain in the Achilles tendon when walking.

The amount of raise required to obtain optimum function is highly variable and requires some degree of trial and error. Where large raises are indicated, it is advisable to start with a smaller raise than required and to gradually increase it over a period of several weeks or months. This is particularly important for older people with balance problems. As a general rule, the heel can be raised to a maximum of 12 mm before a sole raise is also required, as otherwise the ankle is placed in a plantarflexed position and forefoot loading increases (Fig. 12.5). Furthermore, if a large, full-length sole raise is required, it is advisable to incorporate a rocker sole to overcome problems associated with the increased stiffness of the sole, and to hollow out a section of the sole to reduce the total weight of the shoe.

**SHOE STRETCHING AND BALLOON PATCHING**

Modifying the upper of the shoe to accommodate foot deformities and lesions is quite an old technique but one that can be of great benefit in older people who are unable or unwilling to change their footwear. Several shoe stretching devices are commercially available. Traditional shoe stretchers are designed to increase the overall volume of the shoe and consist of a last that can be expanded (by width or length) by the adjustment of springs or screws (Fig. 12.6). Ball-and-ring stretchers are simple tools in which the ball portion is placed inside the shoe in the location of the lesion or prominence, and the ring on the outside of the shoe. For both devices, it is essential that the upper be prepared with stretching fluid (available from footwear retailers) and that the shoe be stretched gradually. It is also important to recognise that, while leather responds very well to stretching, other upper materials do not and may simply split when stretch is applied.

Balloon patching refers to modifying the upper of the shoe by cutting out a portion of the upper corresponding to a bony prominence or lesion and replacing it with a pocket of softer material. Although balloon patching can be quite effective in reducing pressure from dorsal lesions, considerable care needs to be taken to ensure that the stitching required to hold the patch in place does not create additional areas of pressure. Furthermore, to achieve an aesthetically acceptable result, it is essential to accurately match the colour and texture of the upper material being replaced.

**SPECIALIST FOOTWEAR**

Specialist footwear, also referred to as medical grade footwear, can be broadly categorised under two main headings: stock or bespoke. Stock footwear is a mass-produced, off-the-shelf product targeted at the orthopaedic market and generally consists of shoes with extra depth and extra width fittings in a range of styles and colours. Stock footwear is generally more expensive than regular footwear. This type of shoe is ideal
for older people with mild to moderate foot deformities (such as lesser toe deformities and mild hallux valgus) and can be enhanced by the addition of prefabricated or custom orthoses. Bespoke footwear is custom-made for the individual and involves constructing a last from the patient’s foot, using either foam box, plaster or optical scanning techniques. This type of shoe is generally used in older people with severe foot deformity, such as those with rheumatoid arthritis, plantar neuropathic ulceration, foot and ankle trauma or partial amputation (Fig. 12.7). Because of the additional labour involved in assessment and manufacture, bespoke footwear is considerably more expensive than regular or stock footwear.

Protocols for the provision of specialist footwear vary considerably across health services and between countries, and tend to change quite regularly in response to amendments in health financing policies. Readers are therefore advised to consult the most up-to-date guidelines in their region. Nevertheless, several studies have been undertaken that have implications for specialist footwear prescription irrespective of the how footwear is funded. A systematic review of nine trials of specialist footwear in preventing reulceration in people with diabetes concluded that there was some evidence of a protective benefit over regular footwear, particularly in people with severe foot deformity or partial amputation. However, compliance with diabetic footwear is known to be highly variable. In one study, only 22% of patients wore their specialist footwear on a regular basis.

A similar pattern emerges in studies of specialist footwear in people with rheumatoid arthritis. Two trials have indicated that specialist stock footwear is more effective in reducing foot pain than retail footwear; however, compliance is generally poor. In one recent study of 80 patients, 10 refused the specialist footwear outright and only 36 completed the trial. These studies indicate that, while specialist footwear may be effective in those who use it, considerably more work needs to be done to make the footwear acceptable to patients. Issues relating to acceptability of footwear are discussed later in the chapter.

FOOTWEAR, BALANCE AND FALLS

Falls in older people are a major public health problem. One in three people aged over 65 years of age fall within any given year, and this rate increases to 50% in people aged 85 years and above. Several studies have assessed footwear in older people who have fallen and have implicated a wide range of shoe features that may have been responsible, such as...
narrow heels, slippery soles, inadequate fixation, poorly fitting shoes and soft heel counters.\textsuperscript{56–70} Stronger evidence comes from case-control or cohort studies, in which the footwear of fallers is compared to non-fallers. Five such studies have recently been undertaken, with varying results. Kerse et al\textsuperscript{71} assessed footwear in 606 older people in residential care, and found that wearing slippers rather than shoes increased the risk of fractures during the 12-month follow-up period. Keegan et al\textsuperscript{72} examined risk factors for various fall-related fractures in people aged over 45 years and found that medium–high-heeled shoes and shoes with a narrow heel significantly increased the likelihood of all types of fracture, while slip-on shoes and sandals increased the risk of foot fractures as a result of a fall. A study of 4281 people aged over 66 years by Larsen et al\textsuperscript{73} found that those who had fallen in the last 24 hours were four times more likely to have been wearing socks or slippers without a sole. A nested case-control study of 654 people aged over 65 years by Koepsell et al\textsuperscript{74} found that going barefoot or wearing stockings was associated with a tenfold increased risk of falling, with athletic shoes being associated with the lowest risk. Further evaluation of footwear characteristics from this study found that increased heel height was associated with increased risk of falling, whereas greater sole contact area was associated with decreased risk.\textsuperscript{75} Finally, a prospective study by Menz et al\textsuperscript{76} found that, while there were no differences in footwear characteristics between older people who did and did not sustain a fall when outdoors, those who fell while indoors were more likely to be barefoot or wearing socks.

On the basis of these findings, it is difficult to recommend one style of shoe over another to prevent falls. However, a number of features of shoe design have been implicated as having an impact on balance, including heel height, the cushioning properties of the midsole, the slip resistance of the outersole, the method of fixation, the height of the heel collar and midsole geometry.\textsuperscript{77} The following section outlines the available evidence pertaining to the effect of each of these features on balance and is based on a recent update of the literature published in the textbook \textit{Falls in Older People: Risk Factors and Strategies for Prevention}.\textsuperscript{78}

**Heel Height**

Several authors have suggested that the changes in function produced by high-heeled footwear may be responsible for instability and falling in older people.\textsuperscript{2,79–83} High heels are thought to contribute to instability by affecting the position of the centre of mass and by altering the position of the foot when walking.\textsuperscript{84,85} Three recent reports have highlighted the detrimental impact of high heels on balance. Brecht et al\textsuperscript{86} reported that balance performance on a moving platform was significantly worse in a heeled cowboy boot than in a tennis shoe, and suggested that heel elevation may make the wearer more susceptible to falling backwards. Lord & Bashford\textsuperscript{87} have also found that balance ability in older women is detrimentally affected by high heels. In this study, older women’s balance was tested when subjects were barefoot, in their own shoes and in high-heeled shoes (heel height 6 cm). The worst balance performances occurred when women wore high-heeled shoes. Arnadottir & Mercer\textsuperscript{88} found that performance on several balance tests was impaired in elderly women when wearing dress shoes (mean heel height 5 cm) compared to barefoot or when wearing walking shoes (mean heel height 1 cm). In contrast to these findings, Lindemann et al\textsuperscript{89} found no differences in balance when 26 older women wore shoes with a range of heel heights. The highest heel used in this study was 4 cm, suggesting that there may be a critical height at which heel elevation becomes problematic for balance.

Further research needs to be undertaken to ascertain the optimum heel elevation for women’s shoes, as many older women report that they feel safer in a slight heel, and heel elevation may have some beneficial effects in older people with Parkinson’s disease to facilitate forward propulsion.\textsuperscript{90} Habitual wearers of high-heeled shoes may have experienced some changes to the extensibility of posterior soft tissue structures (e.g. calf muscle tightening), which may contribute to greater comfort and possibly safety while wearing these shoes. However, it would appear that heel elevation greater than 6 cm is potentially detrimental to balance and should therefore be avoided.

**Midsole Cushioning**

The use of expanded polymer foam materials in the construction of footwear midsoles enhances the level of comfort the shoe can provide to the wearer and is therefore commonly recommended as a beneficial feature in footwear for older people.\textsuperscript{91,92} However, research undertaken by Robbins and colleagues suggests that the use of thick, soft materials in footwear midsoles leads to instability, as the midsole material...
FOOTWEAR CONSIDERATIONS

induces a state of ‘sensory insulation’, reducing sensory input to the central nervous system regarding foot position.93

To test this hypothesis, Robbins and colleagues (among others) have conducted a number of studies that have evaluated balance ability when older people wear footwear that varies according to the thickness and softness of the midsole material. The Robbins et al studies have found that shoes with thick, soft midsoles have a detrimental effect on the ability of older people to maintain balance when walking on a beam,93 to detect the position of their ankle joint when standing on different surface inclinations94 and to detect the position of their foot when walking.95 The detrimental influence of thick soles was further supported by Sekizawa et al,96 who evaluated foot position sense when subjects stood on a sloped surface and found that subjects underestimated the position of their foot in dorsiflexion when wearing shoes with thick soles (5 cm at heel, 3 cm at forefoot). The suggestion that soft shoes may have detrimental effects on balance has been supported by investigations by Finlay,2 who reported an association between wearing soft slippers and falls, and Frey & Kubasak,67 who found that a large number of older people who fell were wearing cushioned running shoes at the time. It would therefore appear that the proposed interaction between sensory feedback and stability is plausible and that soft soles may contribute to falls. It may therefore be prudent to advise against the wearing of shoes with very soft soles unless there is a specific therapeutic need for extra cushioning.

SLIP RESISTANCE OF FOOTWEAR OUTERSOLES

Accidental falls caused by slipping are a common concern in older people, particularly in countries where snow- and ice-covered pavements are implicated in a large number of injuries to older people during winter months.97,98 Unfortunately, while a number of investigations have attributed falls in older people to slipping or tripping on unstable surfaces such as cracked paths, bathroom tiles or snow, few studies in the gerontology or rehabilitation literature have focused on the role of the outersole of the shoe in these accidents.

Nevertheless, a number of authors have suggested that older people should be advised to avoid shoes with slippery soles – the assumption being that a textured, slip-resistant sole may prevent slip-related accidents.3,79–83 Such a recommendation may not be appropriate in all situations, however, as a number of cases have been reported in which falls are attributed to excessive slip-resistance of the shoe when walking on a pavement or performing a household task.69,99 Despite these observations, it would appear that falls related to excessive slip-resistance are far less common than those resulting from inadequate slip-resistance.

Gait analysis studies have revealed that slipping is most likely to occur when the heel first strikes the ground;97,100,101 therefore, the geometry and texture of the heel section of a shoe may play an important role in preventing slipping accidents. Menz & Lord102 have recently shown that casual shoes vary considerably in their slip-resistance properties. Using a specially-designed force plate apparatus, two types of shoe were tested: lace-up Oxford-style shoes and women’s fashion shoes. The Oxford shoes were modified to produce four different heel configurations; the unmodified Oxford shoe had a flat heel with no flaring or sole texture, the second shoe was modified by flaring the heel laterally by 30°, the third shoe was modified by grinding a 10° bevel into the rear section of the heel and the fourth shoe had a ‘non-slip’ textured material stuck to the sole. The women’s fashion shoes were modified to produce a narrow heel and a broad heel, and each of these shoes was tested with and without a ‘non-slip’ textured material applied to the sole. All shoes were tested on dry and wet bathroom tiles, concrete, vinyl flooring material and terra cotta. Testing revealed that the Oxford shoes offered greater slip resistance than the women’s fashion shoes. The addition of a textured sole material had no effect on slip resistance on wet surfaces and broadening the heel of women’s shoes offered little additional benefit.

The most slip-resistant shoe was the Oxford shoe with the 10° heel bevel, which is consistent with previous reports in the occupational safety literature. A bevel is thought to improve slip resistance by increasing the surface area of the plantar aspect of the sole at heel contact.103 Although heel modification has been found to be of benefit under experimental conditions, it remains to be seen whether such footwear modifications can help prevent slipping in older people. However, a recent study indicates that a specially-designed footwear addition may prevent slipping in older people walking on icy surfaces. The device (the YakTrax® Walker) is an injection-moulded thermoplastic elasto-
The use of high heel collars as a means of improving stability in older people warrants further investigation, as both peripheral sensory loss\textsuperscript{106} and ankle muscle weakness\textsuperscript{107} have been found to contribute to falling. Given that ankle support has been found to improve mechanical stability and ankle position sense in younger people,\textsuperscript{108,109} shoes with high collars may be able to compensate for age-associated declines in sensory and motor function of the foot and ankle. However, such shoes must not be too restrictive, as a certain amount of foot flexibility is required to adapt to uneven terrain when walking.\textsuperscript{110,111}

**Figure 12.8** The Yaktrax® Walker device for preventing slips in icy conditions. (Courtesy of Genesis Marketing Partners.)

mer wrapped in a mesh of metal coils that is strapped on to the sole of the shoe (Fig. 12.8). In a randomised controlled trial of 109 older people, McKiernan\textsuperscript{104} reported that those who wore the device during the winter months had significantly fewer slips and fewer injurious falls than those who wore their regular footwear.

**HEELED COLLAR HEIGHT**

Stability around the heel is widely regarded as a desirable feature when recommending footwear for unstable older people.\textsuperscript{2,80,81,91,92} Lord et al\textsuperscript{105} assessed the balance ability of older women when barefoot and in shoes with standard collar height (Oxford-style shoe) and a raised collar height (eight-laced ‘Doc Marten’ boot). The results revealed that subjects performed better in the high-collared shoe, presumably because the high heel collar provides greater ankle stability and increased proprioceptive feedback compared to standard footwear.

The term *midsole flare* refers to the difference between the width of the midsole at the level of the upper and its width at the level of the outersole. A number of authors have suggested that a large midsole flare is of benefit in older people as it provides a broader base of support, thereby enhancing the stability of the shoe.\textsuperscript{2,79-81,91} No studies have directly evaluated the effect of midsole flaring on balance ability, although associations between narrow heels and falls,\textsuperscript{75} and narrow heels and fall-related fractures\textsuperscript{72} have been recently reported. The association with fractures suggests that, if a fall does occur, the loss of balance when wearing narrow heels may result in greater sideways impact.

Theoretically, midsole flaring should improve mechanical stability by increasing the surface contact area of the shoe–ground interface.\textsuperscript{112,113} However, studies have also found that large midsole flares may make the foot pronate more during gait\textsuperscript{114,115} and there is also the possibility that a large midsole flare may make the wearer susceptible to tripping by contacting the contralateral limb during the swing phase of gait. Whether these proposed detrimental effects of midsole flaring have significant ramifications for stability in older people is uncertain. Therefore, no absolute recommendations can yet be developed regarding the benefits or otherwise of midsole flaring in footwear for older people. However, given that recent work suggests that impaired lateral stability is associated with falls\textsuperscript{116} and that people who wear shoes with narrow heels are more likely to fall\textsuperscript{75} and suffer fractures,\textsuperscript{72} any attempt to improve the control of lateral movements of the centre of mass may be beneficial.
METHOD OF FIXATION

The method used to attach the shoe to the foot may also play a role in falls risk. It is a common clinical observation that many elderly people wear shoes with inadequate fixation, such as slippers, moccasins and soft, canvas slip-on shoes. These types of shoe promote a shuffling gait pattern and may become separated from the foot when walking, thereby acting as an external tripping hazard. In a recent study of 95 older people who had been admitted to hospital following a fall-related hip fracture, Sherrington & Menz found that those who suffered a trip were three times more likely to be wearing shoes without laces, zips or Velcro® fastening. Two of the subjects who suffered a trip and were wearing these types of shoe specifically blamed their footwear for the fall: one reported that her slipper ‘got stuck’, causing her to lose balance, while another stated that her mocassin ‘slipped off’ her foot, causing her to trip over it. The association recently reported between the wearing of slip-on shoes and fall-related foot fracture adds further weight to this suggested mechanism.

Although it is difficult to confirm that the shoes were responsible for the fall, it would seem prudent to recommend that older people wear shoes that are firmly fitted to their feet.

ADVISING OLDER PEOPLE ABOUT FOOTWEAR

The concept of the ‘ideal’ shoe is somewhat nebulous, as what is ideal for one individual may be totally inappropriate for another. Furthermore, the functional requirements of footwear vary considerably according to environmental and physical demands, e.g. indoor versus outdoor shoes, walking shoes versus running shoes, etc. Nevertheless, there are some general principles that apply to most individuals and situations and form the basis of footwear recommendations for older people. The most fundamental requirement is that the shoe should fit properly, in order to reduce the risk of tissue damage and the development of keratotic lesions. The shoe should also be stable, particularly in older people with underlying balance problems. Based on the literature pertaining to the effect of shoe features on balance, it can be concluded that older people should wear shoes with thin, flat, broad, bevelled heels constructed from a firm material, textured soles to improve traction, laces to provide adequate fixation and possibly the addition of ankle support by the use of a high heel collar.

However, one of the more frustrating aspects of managing foot problems in older people is that it is often difficult to convince patients to change their footwear. Compliance with use of therapeutic footwear has been shown to be low in people with diabetes and rheumatoid arthritis, and a recent survey of emergency department physicians indicated that compliance with footwear recommendations to prevent falls was poor, because of ‘stubbornness and vanity’. Similarly, the American podiatrist Bill Rossi considers advising patients to change their footwear to be ‘an exercise in eternal futility’. Nevertheless, many aspects of behavioural change required to improve health are difficult to achieve (e.g. weight loss, exercise, smoking cessation) and it would be negligent to ignore these issues simply because they are difficult.

When providing footwear advice to older patients, it is worth considering the underlying concepts of the Health Belief Model. This model suggests that a patient’s decision to carry out a particular health-protective behaviour (such as changing footwear) is influenced by how vulnerable they perceive themselves to be to the particular health problem, how serious they perceive the particular health condition to be, the benefits that they perceive the health protective behaviour will produce and what barriers there are to carrying out the behaviour. For example, a falls prevention study of 652 older people indicated that many were unaware of the risks of inappropriate shoes that and the main barriers to wearing more ‘sturdy’ shoes were difficulty putting them on, expense and concern about their appearance. Considering how such factors differentially affect individual patients may assist in the development of more effective strategies to enhance compliance with footwear recommendations.

The provision of clear written material is an essential part of this process. The Footwear Suitability Scale, originally designed for use in people with diabetes, is a useful clinical tool that can also be administered to non-diabetic patients. The scale consists of eight questions for patients to complete regarding the suitability of their footwear (Table 12.1). With regard to footwear and falls, Lord et al have developed a simple poster of what constitutes a safe and unsafe shoe, based on evidence from the literature (Fig. 12.9). Both tools are simple and quick
Table 12.1 Footwear Suitability Scale

<table>
<thead>
<tr>
<th>Question</th>
<th>Reason</th>
<th>Tick box</th>
</tr>
</thead>
<tbody>
<tr>
<td>1  Is the heel of your shoe less than 2.5 cm (1 in)?</td>
<td>As the height of your heel increases, the pressure under the ball of your foot becomes greater. Increased pressure can lead to callos and ulceration</td>
<td></td>
</tr>
<tr>
<td>2  Does the shoe have laces, buckles or elastic to hold it onto your foot?</td>
<td>If you wear slip-on shoes with no restraining mechanism, your toes must curl up to hold the shoes on. This can cause the tops of your toes to rub on your shoes, leading to corns and calluses. Secondly, the muscles in your feet do not function as they should to help you walk. Instead, they are being used less efficiently to hold your shoes on</td>
<td></td>
</tr>
<tr>
<td>3  Do you have 1 cm (approximately thumb nail length) of space between your longest toe and the end of your shoe when standing?</td>
<td>This is the best guide for the length of the shoe, as different manufacturers create shoes that are different sizes. Your toes should not touch the end of the shoe as this is likely to cause injury to the toes and place pressure on the toenails</td>
<td></td>
</tr>
<tr>
<td>4  Do your shoes have a well padded sole?</td>
<td>Shoes should have a supportive, but cushioned sole to absorb any shock and reduce pressure under the feet</td>
<td></td>
</tr>
<tr>
<td>5  Are your shoes made from material that breathes?</td>
<td>A warm, moist environment can harbour organisms, such as those that cause fungal infections</td>
<td></td>
</tr>
<tr>
<td>6  Do your shoes protect your feet from injury?</td>
<td>The main function of footwear is protection from the environment. Ensure your shoes are able to prevent entry of foreign objects that can injure the foot. If you have diabetes, a closed toe is essential to prevent injury to the foot</td>
<td></td>
</tr>
<tr>
<td>7  Are your shoes the same shape as your feet?</td>
<td>Many shoes have pointed toes and cause friction over the tops of the toes, which can lead to corns, callos and ulceration. If you can see the outline of your toes imprinted on your shoes, then the shoe is probably the wrong shape for your foot</td>
<td></td>
</tr>
<tr>
<td>8  Are your shoes the same shape as your feet?</td>
<td>Many shoes have pointed toes and cause friction over the tops of the toes, which can lead to corns, callos and ulceration. If you can see the outline of your toes imprinted on your shoes, then the shoe is probably the wrong shape for your foot</td>
<td></td>
</tr>
<tr>
<td>9  Is the heel counter of your shoe firm?</td>
<td>Hold the sides of the heel of your shoe between the thumb and forefinger and try to push them together. If the heel compresses, it is too soft to give your foot support. The heel counter provides much of the support to the shoe and must be firm to press</td>
<td></td>
</tr>
</tbody>
</table>

If you have not put a tick in every box, your footwear is probably not protecting and supporting your foot as it should.

SUMMARY

Footwear is a major consideration in the care of older people, as ill-fitting or inappropriate footwear may contribute to the development of foot problems and increase the risk of falls. Footwear modification is a useful conservative management strategy for a wide range of foot problems and can enhance the effects of other treatments. Finally, the role of footwear advice should not be overlooked, as changing footwear may, in and of itself, lead to the resolution of many foot complaints.
FOOTWEAR CONSIDERATIONS

A firm heel collar to provide stability
A bevelled heel to prevent slipping
A broad, flared heel to maximise contact with the ground

What makes a shoe safe?

Laces ensure the shoe 'holds' onto your foot when walking
A thin, firm midsole so you can 'feel' the ground underneath
A textured sole to prevent slipping

What makes a shoe unsafe?

Soft or stretched uppers make your foot slide around in the shoe
High heels should be avoided as they impair stability when walking
Narrow heels make your foot unstable and can cause ankle sprains

Lack of laces means your foot can slide out of your shoe
Slippery or worn soles are a balance hazard, particularly in wet weather

Figure 12.9 What makes a shoe safe/unsafe handout.

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