

FOOT AND ANKLE | RECONSTRUCTION | TRAUMA

Philosophy of Foot and Ankle Surgery

Mechanics, biology and the recovery of function



Mr Peyman Bakhshayesh

MD, PhD, MBA

Consultant Trauma and Orthopaedic Surgeon
Specialist in foot and ankle surgery and trauma

COMPLETE ILLUSTRATED EDITION | OCTOBER 2026

COMPLETE ILLUSTRATED EDITION

Philosophy of Foot and Ankle Surgery

Mechanics, biology and the recovery of function

Mr Peyman Bakhshayesh

MD, PhD, MBA

Consultant Trauma and Orthopaedic Surgeon Specialist in foot and ankle surgery and trauma

A substantial clinical book connecting the patient's story with anatomy, loading, tissue health, reconstruction and meaningful recovery. It brings together elective surgery, sports injury and the principles of major trauma care.

First complete illustrated edition 14 October 2026

About this edition

This edition brings together the author's supplied Chapters 1 and 3 to 8, with a new Chapter 2 on assessment and treatment planning and a concluding Chapter 9 on recovery. The regional chapters preserve the substance of the original dictation and manuscripts, with consistent terminology, updated evidence and additional material on the conditions described on the author's clinical websites.

The book is written for clinicians, trainees and readers seeking an informed understanding of foot and ankle treatment. It is a referenced narrative account of clinical reasoning, not a systematic review, an individual treatment plan or a stand-alone operative manual. Personal techniques and practice pathways are identified as the author's approach. Their inclusion does not establish comparative superiority or universal suitability.

The guiding question is how the proposed treatment can help this person walk, work and live more comfortably. An anatomical correction, an image showing union and a meaningful functional recovery are related but different outcomes. Treatment must account for mechanical stability, biological healing, the patient's priorities and the practical organisation of rehabilitation.

Sources were checked and reconciled for this edition in October 2026. Guidance and products can change; clinical decisions require current professional standards, the relevant device instructions and local pathways. Evidence from one joint, procedure or patient group should not be automatically transferred to another. Unpublished author manuscripts are described as such.

All supplied chapter illustrations have been retained. Additional original teaching artwork comes from the author's Painful Accessory Navicular presentation. The cover and pictorial scenes are conceptual artwork; they do not depict actual patients or demonstrate treatment results. Diagrams simplify anatomy and mechanical principles and should be read with their captions.

The author practises in trauma and orthopaedics and has a professional interest in the treatments discussed. This educational book appears on his professional and public websites. Practice examples and proposed techniques are not presented as independently audited success rates. No identifiable patient records are reproduced.

The supplied rheumatoid-foot resource and hospital procedure leaflets informed the scope of patient explanations. They are not reproduced as the author's original work. The source notes distinguish these materials, the author's publications, original chapter content and current clinical references.

Copyright © 2026 Mr Peyman Bakhshayesh. All rights reserved. Original source works retain their own rights.

Contents

The chapter sequence preserves the author's regional teaching structure. Readers may turn to Chapter 6 first for a detailed biomechanical foundation. Page numbers and chapter links refer to this complete edition.

01 The development of a surgical philosophy	5
02 Assessment and treatment planning	13
03 The ankle and hindfoot	20
04 Midfoot conditions and reconstruction	37
05 Forefoot conditions and balanced reconstruction	52
06 Biomechanics of the Foot	67
07 Sports injuries tendons and return to activity	87
08 Foot and Ankle Trauma	106
09 Recovery and the measure of success	128
Condition directory	136
Terms used in the book	137
Source notes and related publications	138

Clinical use

Condition-specific treatment choices sit within the assessment principles in Chapter 2 and the recovery framework in Chapter 9. References follow their relevant chapters; bracketed identifiers link directly to the corresponding entries. The condition directory at the end of the book provides a second route into the text.

CHAPTER 01

01 The development of a surgical philosophy

The development of a surgical philosophy

I write this book from the meeting point of elective foot and ankle surgery, major trauma and limb reconstruction. My purpose is to explain how I understand the patient's problem, how I connect that problem to anatomy and biomechanics, and how I choose a treatment whose benefits are meaningful in the patient's life. A technically satisfactory operation is only one part of that responsibility. The treatment must also respect the patient's biology, circumstances and capacity for recovery.



Figure 1.1 Movement is the context of treatment. Original conceptual cover artwork from the author's opening chapter; this illustration does not depict an actual patient or a treatment result.

My medical journey began at Shiraz Medical School, where I graduated with an MD in 1996. Between 1996 and 1998, I served as a military doctor in the Iranian Air Force, working in an accident and emergency setting with responsibilities broadly comparable to those of a senior house officer. Emergency medicine introduced me to the need to assess the whole patient, recognise priorities and make decisions within the resources available.

In 1998, I left Iran for Germany. At Humboldt University in Berlin, I studied German and pursued interests in philosophy, politics and economics. These interests

contributed to my understanding of reasoning and responsibility, although my subsequent career remained centred on medicine. In 1999, I moved to Sweden, learned Swedish, gained experience within the healthcare sector and completed language preparation for overseas medical doctors. After the TULE examination and the required Swedish clinical training, including service as an AT-läkare, I entered the Swedish orthopaedic training programme in 2004.

I completed specialist training in October 2009. Further fellowship experience at Uppsala University Hospital developed my skills across shoulder, knee, hand, foot and ankle surgery. In March 2010, I began consultant practice at Västerås Hospital in Västmanland, with a particular focus on elective foot and ankle surgery. This work strengthened my interest in the relationship between local pathology and the mechanics of the entire lower limb. [P1]

Training across trauma and reconstruction

As major trauma care became more centralised, my interest in polytrauma grew. In August 2011, I moved to the United Kingdom for a year of fellowship training in Birmingham under Professor Keith Porter. The year included six months in complex knee surgery and six months in limb reconstruction and foot and ankle surgery. I worked with the knee and reconstruction teams, including Mr Tanweer Ashraf, Ms Deepa Bose and Mr Ali. These experiences widened my understanding of deformity, fixation, soft tissues and the organisation of specialist care.

In 2012, I returned to Västerås to a practice divided approximately equally between trauma and foot and ankle surgery. I led the foot and ankle service until moving to Karolinska University Hospital in August 2014. My initial role there included complex foot and ankle surgery within Greater Stockholm. As service arrangements evolved and more elective conditions were managed in surrounding hospitals, I became increasingly involved in polytrauma care.

From October 2018 to October 2019, I undertook a post-CCT fellowship at Imperial College Healthcare, concentrating on pelvic and acetabular surgery and hip replacement and revision. From October 2019 to October 2020, I continued fellowship training at the Royal London Hospital in polytrauma, limb reconstruction and bone infection, working with Nima Heidari and Alexandros Vris. I defended my doctoral thesis at Karolinska Institutet on 13 November 2020. In February 2021, I began consultant practice in major trauma at Leeds, maintaining a particular focus on foot and ankle surgery. [P1, P2]

For me, the value of multiple fellowships lies in translating principles between fields. Limb reconstruction teaches the importance of alignment and tissue viability. Arthroplasty requires attention to motion, fixation and future revision. Pelvic and acetabular surgery develops three-dimensional reasoning. Trauma care places every technical decision within the patient's physiological condition and the capabilities of the treating team.

Combining these perspectives allows me to work with vascular surgeons, plastic surgeons, infection specialists and other reconstructive colleagues when a complex foot or ankle problem requires their expertise. The aim is to recognise the limits of an

isolated procedure and organise the care that the particular patient needs. Knowledge becomes useful when it is connected to judgement, collaboration and a practical recovery plan.

Understanding the foot within the person

Foot and ankle surgery has developed through better imaging, a more detailed understanding of biomechanics and increasingly specialised reconstructive techniques. These developments help us identify problems that were previously difficult to describe. They also create a responsibility to distinguish an anatomical finding from a clinically important disorder.

The foot must accept load, adapt to the ground and contribute to propulsion. It does so through coordinated movement between bones, joints, ligaments, tendons and muscles. Sensation and motor control guide that movement; circulation and skin integrity allow the tissues to tolerate it. The ankle, hindfoot, midfoot and forefoot therefore form a connected functional system. [P3]

My starting point is the patient's account. Where is the pain? When does it occur? What has changed in walking, footwear, work, sport or independence? A patient who cannot walk to the shops and a patient who cannot return to demanding employment may have similar images but different treatment priorities. Pain, instability, deformity, stiffness and weakness should be considered separately before their relationships are explained.

The clinical examination should connect the reported symptoms to loading and movement. It includes gait observation, standing alignment, skin and callus distribution, tenderness, joint motion, tendon function, flexibility of deformity and neurological and vascular assessment. The knee, hip and overall lower-limb alignment may also influence the foot's behaviour. A scan becomes useful when it answers a question arising from this assessment.

This approach continues the philosophy developed in my book on major trauma: understand the mechanism and the patient, prepare the service, and preserve the possibility of meaningful functional recovery. In elective foot and ankle practice, the timescale is usually different, but the duty to connect treatment with the patient's future remains.

In my teaching on the painful accessory navicular, I have emphasised that the visible anatomical variant must be considered alongside the location of pain and the mechanical environment. The same reasoning applies throughout this book. The surgeon must be able to explain why a proposed intervention is expected to improve this person's symptoms and function.

Gait and the mechanics of walking

A gait cycle runs from initial contact of one foot to its next initial contact. In comfortable level walking, stance occupies approximately 60% of the cycle and swing approximately 40%; these proportions change with speed and pathology. Stance is the period of ground contact, while swing advances the limb toward the next step. [P3]

The stance phase can be understood through successive heel, ankle and forefoot rockers. During loading response, the heel rocker permits the foot to lower toward the ground. During midstance, the tibia progresses over the planted foot through the ankle rocker. With heel rise, progression moves toward the forefoot, and the forefoot rocker contributes to the transition toward toe-off. Coordinated hindfoot and midfoot motion accompanies these events. [P3]

Clinical gait analysis asks where this sequence is interrupted. Pain, restricted ankle dorsiflexion, calf weakness, instability or forefoot stiffness may alter progression and provoke compensatory movement. My treatment plan must consider the mechanical consequence of changing one part of that sequence, especially when reconstruction deliberately changes alignment or removes joint motion.

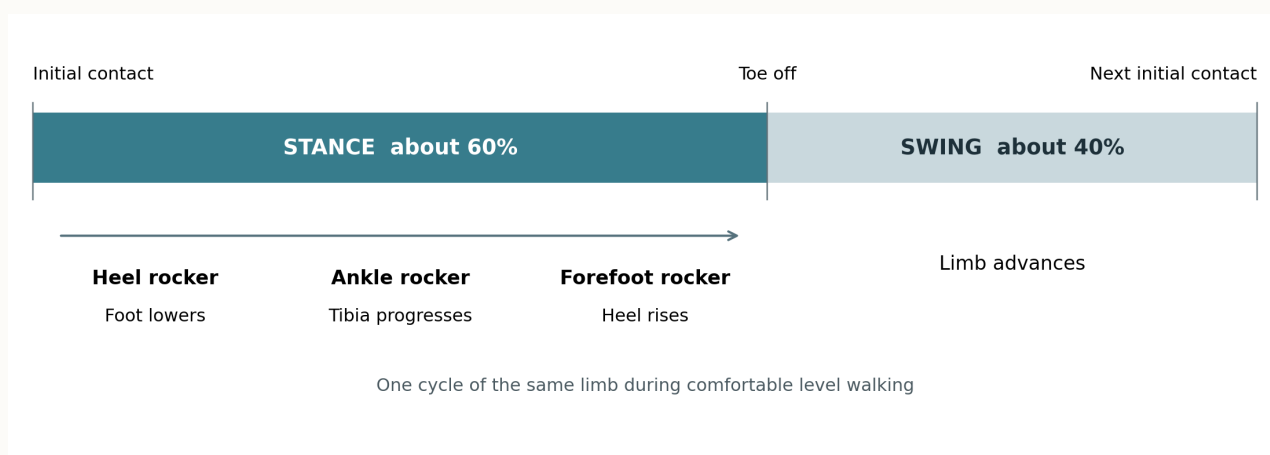


Figure 1.2 A simplified gait cycle and its principal stance rockers. Timing is approximate for comfortable level walking; the rockers describe function rather than fixed subphase boundaries. Original educational schematic.

Imaging guided by the clinical question

Imaging should be selected to resolve a defined uncertainty. Appropriate radiographs are usually the initial examination for chronic foot pain. Weight-bearing views are particularly important when the question concerns alignment or deformity, provided standing is clinically appropriate. CT, MRI and ultrasound answer different questions and should be chosen accordingly. [P4]

Weight-bearing CT can show three-dimensional relationships under load and is valuable in selected deformity assessments and surgical planning. Expert consensus supports its use, when available, in planning surgery for progressive collapsing foot deformity. A standing scan remains a static assessment; it does not reproduce the complete walking cycle. [P5]

SPECT CT may help when several joints are abnormal or the symptomatic site remains unclear. Increased uptake must be interpreted with symptoms, examination and other imaging; it does not by itself establish the pain generator. [P6]

Advanced techniques can register CT-derived bone models to biplanar fluoroscopic images to examine motion. These are specialist or research methods. My published work on CT-based motion analysis also illustrates the potential for three-dimensional assessment of rotational deformity, but that study should not be equated with routine

dynamic gait analysis. Gait laboratories and instrumented assessment can supplement selected clinical evaluations. [P7, P8]

Different investigations answer different clinical questions

Examination	Principal contribution
Weight-bearing radiographs	Overall alignment and joint relationships during standing; a starting point for many deformity assessments.
CT	Detailed bone and joint architecture, complex fractures, coalition, deformity and assessment of fusion where indicated.
MRI	Soft tissues, marrow and osteochondral pathology, selected according to the clinical question.
Ultrasound	Targeted assessment of superficial soft tissues and dynamic tendon behaviour where appropriate.
SPECT CT	Selected difficult localisation problems, combining tracer activity with anatomical information.

Progressive collapse and cavovarus

Some adult problems arise from a congenital or longstanding developmental foot shape. Others develop through injury, degeneration, inflammatory disease or neurological change. Establishing the origin, progression and flexibility of a deformity matters because similar appearances may require different treatment strategies.

The term progressive collapsing foot deformity, or PCFD, describes a complex three-dimensional adult acquired deformity previously often called adult acquired flatfoot. Posterior tibial tendon dysfunction may contribute, but the disorder cannot be reduced to that tendon alone. Ligament failure, joint relationships and bone shape also matter. Assessment must distinguish a flexible deformity from a rigid or arthritic one and identify the components of collapse. [P9]

A longstanding painless low arch is not automatically PCFD. Neuropathic Charcot collapse is also a distinct clinical problem. Body weight and loading deserve attention, while diabetes, neuropathy, vascular disease and reduced bone quality influence assessment and the capacity for safe treatment and healing. Their presence should prompt individual evaluation rather than a uniform assumption about the cause or course of collapse.

Cavovarus combines an increased arch with a varus tendency of the hindfoot, often with associated forefoot deformity. It may reflect muscle imbalance, neurological disease, residual childhood deformity or other causes. A high arch alone does not establish its aetiology. Charcot-Marie-Tooth disease is an important consideration, alongside other peripheral nerve or central neurological disorders. [P10]

I consider neurological history and examination essential in every cavovarus assessment. Progression, asymmetry, family history, weakness, altered sensation and reflex changes guide the need for neurological referral, electrodiagnostic studies, genetic evaluation or spinal investigation. Further tests should follow the clinical findings. [P10]

The reconstructive question is how much of the deformity is flexible, which structures drive it, where the foot is overloaded and whether joints remain suitable for preservation. A correction that overlooks continuing muscle imbalance or an adjacent deformity may leave the original mechanical problem unresolved.

Arthritis and the biological context

Trauma has a particularly important role in ankle osteoarthritis. Previous fracture, cartilage injury, residual malalignment and chronic instability may create a joint that deteriorates over time. In a specialist cohort of 406 ankles, Valderrabano and colleagues attributed 78% of osteoarthritis to trauma. This is a finding from a clinical cohort, rather than a universal prevalence estimate. [P11]

The same cause should not be assumed for every arthritic joint in the foot. Primary degeneration, inflammatory disease and other arthropathies also occur. The history and examination must therefore establish the likely disease process and identify which joint or joints are clinically responsible. An ankle with end-stage arthritis presents a different decision from a painful first metatarsophalangeal joint or an arthritic midfoot.

Modern disease-modifying treatment has substantially changed rheumatoid arthritis care. Conventional, biological and targeted therapies are used within defined pathways to control inflammation and limit further damage. However, medical control does not automatically reverse established deformity, stiffness or mechanical disability. Persistent functional problems may still require footwear, orthotic, rehabilitation or surgical assessment alongside rheumatological care. [P12]

Systemic lupus erythematosus and systemic sclerosis require their own disease-specific approaches. Vascular involvement, skin changes, organ disease and treatment-related risks may alter the assessment and operative plan. Improvement in rheumatoid arthritis treatment should not be generalised as an identical biological treatment response across these different disorders. [P13, P14]

I regard the biological context as part of the reconstructive diagnosis. Skin, circulation, sensation, infection risk and the capacity of bone and soft tissues to heal must be assessed alongside alignment. A sound mechanical idea requires a biological environment in which it can succeed.

For established ankle arthritis, replacement and fusion illustrate the need for individual choice. Both can improve symptoms in appropriately selected patients, but they change the limb differently and carry different risks. The TARVA randomised trial reinforces the importance of explaining the alternatives; it does not justify one operation for every patient. [P15]

Treatment decisions and the organisation of recovery

Nonoperative care is an active part of treatment. Depending on the diagnosis, it may include footwear, orthoses or bracing, modified loading, physiotherapy, attention to body weight and appropriate symptom relief. Its aims and progress should be reviewed. Urgent conditions require timely pathways.

When I recommend surgery, I should explain the problem, the proposed mechanical change, the alternatives and the expected benefit. Joint preservation, alignment correction, tendon reconstruction, fusion and replacement are different strategies. Their indications belong to the condition-specific chapters.

Recovery begins in the planning stage. Immobilisation, wound review, weight-bearing restrictions, mobility aids and rehabilitation must be explained. Driving, work, home access and support influence feasibility. Bone union, soft-tissue healing and functional recovery are different milestones; estimates must be specific to the patient and operation.

Material risks may include wound problems, infection, nerve injury, venous thromboembolism, persistent pain, stiffness, failed union, recurrence and further surgery. The later chapters explain procedure-specific risks and the limits of outcome evidence, alongside expected benefits.

Physiotherapists, nurses, orthotists, podiatrists and medical colleagues contribute to recovery. Complex cases may require vascular, plastic, neurological, rheumatological or infection expertise. Organisational skill connects the consultation-room decision to the care the patient can receive.

How to read this book

The chapters retain the regional sequence of my original dictation. Chapter 2 establishes a common assessment and treatment approach; Chapters 3 to 5 examine the ankle, hindfoot, midfoot and forefoot. Chapter 6 develops the biomechanics that support these decisions and can be read early by readers who prefer a mechanical foundation. Chapter 7 considers sports injuries and tendon disorders. Chapter 8 follows the injured limb from mechanism and emergency priorities to reconstruction. Chapter 9 returns to rehabilitation and the meaning of recovery.

This regional structure is a teaching framework. A patient rarely presents as one isolated chapter. Each discussion connects symptoms, mechanics and biology with useful investigations, treatment alternatives and recovery. The intended outcome is a foot and ankle that serve the patient's life as well as the condition and available treatment allow.

References for Chapter 1

[P1] Circle Health Group. Mr Peyman Bakhshayesh. Consultant biography. [Read source](#)

[P2] Karolinska Institutet. Ny avhandling om bäckenfraktur. Doctoral thesis announcement and defence on 13 November 2020. [Read source](#)

[P3] Brockett CL, Chapman GJ. Biomechanics of the ankle. *Orthopaedics and Trauma*. 2016;30(3):232-238. doi:10.1016/j.mporth.2016.04.015. [Read source](#)

- [P4]** American College of Radiology. ACR Appropriateness Criteria Chronic Foot Pain. Current online narrative. [Read source](#)
- [P5]** de Cesar Netto C, et al. Consensus for the Use of Weightbearing CT in the Assessment of Progressive Collapsing Foot Deformity. *Foot Ankle Int.* 2020;41(10):1277-1282. doi:10.1177/1071100720950734. Expert consensus. [Read source](#)
- [P6]** Parthipun A, et al. 99mTc-HDP SPECT-CT Aids Localization of Joint Injections in Degenerative Joint Disease of the Foot and Ankle. *Foot Ankle Int.* 2015;36(8):928-935. doi:10.1177/1071100715579263. [Read source](#)
- [P7]** Ito K, et al. Direct assessment of 3D foot bone kinematics using biplanar X-ray fluoroscopy and an automatic model registration method. *J Foot Ankle Res.* 2015;8:21. doi:10.1186/s13047-015-0079-4. [Read source](#)
- [P8]** Bakhshayesh P, et al. A novel technique to assess rotational deformities in lower extremities using CT-based motion analysis. *Sci Rep.* 2021;11:21123. doi:10.1038/s41598-021-00532-y. [Read source](#)
- [P9]** Myerson MS, et al. Classification and Nomenclature: Progressive Collapsing Foot Deformity. *Foot Ankle Int.* 2020;41(10):1271-1276. doi:10.1177/1071100720950722. Expert consensus. [Read source](#)
- [P10]** British Orthopaedic Foot and Ankle Society. The Cavovarus Foot. BOFAS Hyperbook. [Read source](#)
- [P11]** Valderrabano V, Horisberger M, Russell I, Dougall H, Hintermann B. Etiology of Ankle Osteoarthritis. *Clin Orthop Relat Res.* 2009;467:1800-1806. doi:10.1007/s11999-008-0543-6. [Read source](#)
- [P12]** National Institute for Health and Care Excellence. Rheumatoid arthritis in adults management. NICE guideline NG100. Current online recommendations. [Read source](#)
- [P13]** Fanouriakis A, et al. EULAR recommendations for the management of systemic lupus erythematosus: 2023 update. *Ann Rheum Dis.* 2024;83:15-29. doi:10.1136/ard-2023-224762. [Read source](#)
- [P14]** Del Galdo F, et al. EULAR recommendations for the treatment of systemic sclerosis: 2023 update. *Ann Rheum Dis.* 2025;84(1):29-40. doi:10.1136/ard-2024-226430. [Read source](#)
- [P15]** Goldberg AJ, Chowdhury K, et al. Total Ankle Replacement Versus Arthrodesis for End-Stage Ankle Osteoarthritis: A Randomized Controlled Trial. *Ann Intern Med.* 2022;175:1648-1657. doi:10.7326/M22-2058. [Read source](#)

CHAPTER 02

02 Assessment and treatment planning

Begin with the life the foot must support

I regard the consultation as the first part of treatment. Before choosing an operation, I need to understand what the patient is trying to recover. The immediate complaint may be ankle pain, a prominent bunion or an unstable foot, but the important consequence may be losing the ability to work, exercise, walk with a partner or remain independent. A diagnosis acquires clinical meaning when it explains that limitation. The same deformity can be acceptable to one person and disabling to another, and the same reconstruction can have different value in different lives.

The assessment therefore has two connected tasks. One is to identify the tissue or mechanical problem that best explains the symptoms. The other is to determine whether changing that problem is likely to improve the person's function at an acceptable cost and risk. I should be able to describe the link between these tasks in ordinary language. If the explanation depends entirely on a radiograph, an angle or the name of an operation, the reasoning is incomplete. The patient needs to understand what is being treated and why.

History: reconstruct the problem before naming it

I ask the patient to locate the symptoms as precisely as possible and describe their beginning, progression and relationship to activity. A single episode of injury, a gradual change in training, a longstanding deformity and a recently hot swollen foot suggest different pathways. The history of an apparently minor injury deserves attention when walking has never returned to normal. Previous fractures, dislocations, infections and operations may explain altered alignment, scars, retained implants or a compromised soft-tissue envelope. Previous records and images can clarify what happened more reliably than assumptions based on the current appearance.

Pain during the first steps after rest, pain at push-off, pain on uneven ground and pain at night should be explored rather than treated as interchangeable descriptions. I ask about swelling, giving way, catching, numbness, weakness, shoe pressure and the distance or duration of walking that brings symptoms on. These features guide a differential diagnosis; none is a diagnosis by itself. The patient may have more than one problem. A painful arthritic ankle and a painful plantar callus, for example, may interact but still need separate explanations.

The treatment history is equally informative. Which shoes, supports, exercises, medicines or injections were tried, for how long and with what result? A statement that physiotherapy failed may conceal an exercise programme intended for a different diagnosis, inadequate access, excessive pain during loading or uncertainty about the instructions. I ask what the patient found helpful and what made matters worse. The

aim is to learn from prior treatment and avoid repeating an ineffective intervention without a revised rationale.

Examination: observe the whole limb under meaningful conditions

Where it is safe, I begin by watching the patient rise, stand and walk in their usual footwear and then without it. Gait shows the practical expression of pain and compensation: shortened stance, avoidance of push-off, an externally rotated foot or difficulty controlling heel rise. Footwear reveals the environment in which the foot spends much of its day. Wear, tight areas and the available toe-box space can be more relevant than an isolated measurement made on the examination couch. The knee, hip and opposite limb may influence what the affected foot can achieve.

Standing examination assesses the arch, heel position, forefoot relationship and distribution of loading. Seated or supine examination then explores which components are flexible and which remain fixed. I distinguish motion at the ankle from motion obtained through neighbouring joints and consider calf tightness with the knee in different positions. Palpation must reproduce a recognisable symptom rather than simply identify any tenderness. Tendon testing, ligament examination, heel-rise assessment and appropriate deformity tests are selected to answer the question raised by the history; painful acute injuries should not be subjected to forceful testing.

Skin, scars, callus, ulcers, temperature, sensation, motor function and circulation are part of the reconstructive examination. They establish whether the proposed correction can heal and whether the patient can protect it. A normal-looking foot can have impaired protective sensation, while a deformed foot may remain comfortable and functional. When pulses or other vascular findings are concerning, further assessment is required before elective reconstruction. The examination is not complete until the local anatomy has been considered alongside the patient's capacity to heal and mobilise.

Recognise the conditions that change the timetable

Some findings require an urgent pathway rather than a routine discussion of footwear or surgery. After injury, a cold or poorly perfused foot, a dislocation threatening the skin, an open wound communicating with a fracture or new progressive neurological loss requires immediate assessment. Escalating pain, particularly pain out of proportion to the injury or with passive movement, raises concern for compartment syndrome. The presence of a pulse does not make a severely painful swollen limb reassuring. Serial examination, clear documentation and senior decision-making matter when the clinical picture is evolving. [A1, A2]

A rapidly deteriorating wound, spreading infection, systemic illness or an acutely painful hot joint also demands timely investigation and treatment. Infection should not be dismissed because there is a plausible mechanical explanation or a previous diagnosis of gout. Persistent unexplained pain, a growing mass or symptoms poorly accounted for by the examination should widen the differential and prompt appropriate investigation. The practical principle is to recognise when the ordinary elective pathway

no longer fits. An elegant reconstructive plan has no value if it delays treatment of the condition that threatens the patient or limb.

Separate mechanical deformity, inflammatory disease and neuropathic collapse

Mechanical overload and systemic disease can coexist. A patient with inflammatory arthritis may have active synovitis, established joint destruction, tendon imbalance and shoe-pressure problems at the same time. Treating the deformity does not replace control of the inflammatory disease, and medical treatment does not necessarily reverse fixed structural damage. Persistent synovitis of uncertain cause warrants specialist assessment. Involvement of the small joints of the foot or several joints should heighten concern for inflammatory arthritis and support urgent rheumatology referral rather than waiting for every test to become abnormal. [A3]

A hot swollen foot in a person with diabetes and neuropathy belongs to a different diagnostic pathway from a longstanding flexible flat foot. Acute Charcot neuroarthropathy can occur with little pain. NICE advises rapid referral of suspected acute Charcot disease to the multidisciplinary foot service, within one working day for triage within a further working day, with non-weight-bearing treatment while definitive specialist care is arranged. Infection and vascular disease must also be considered. Routine orthotic treatment or an elective reconstruction appointment should not delay that assessment. [A4]

The reconstructive importance of these distinctions is considerable. In progressive collapsing foot deformity, I ask which ligament, tendon and joint relationships have failed and whether the deformity remains correctable. In cavovarus, I ask whether an underlying neurological disorder or continuing muscle imbalance is driving the shape. In a neuropathic foot, protection, ulcer risk and the biological environment may dominate the decision. Similar silhouettes do not imply similar disease, similar urgency or the same operation.

Use imaging to resolve a question

Imaging should refine a clinical explanation, not replace one. For chronic foot or ankle symptoms, plain radiographs are generally the initial examination. Standing views are particularly valuable when the question concerns alignment, joint loading or deformity, provided weight bearing is clinically appropriate. A non-weight-bearing image may underestimate a load-dependent change, but standing should not be forced in an unsafe acute injury. The request should state the suspected problem and relevant history so that the views answer the question. [A5, A6]

CT is helpful when the important uncertainty concerns bony architecture, articular fragmentation, union or three-dimensional alignment. MRI can clarify occult bone injury and soft-tissue or osteochondral pathology; ultrasound can address selected tendon and other superficial soft-tissue questions. Each investigation has limitations. Abnormal signal or degenerative change may be present without explaining the patient's main symptom. Before ordering another scan, I ask what decision its result could change and how its findings will be reconciled with the examination.

Weight-bearing CT and other specialist investigations may add useful detail in complex reconstruction. They do not remove the need to observe function. A static image cannot show the entire walking cycle or explain every adaptation to pain. When several joints are abnormal, the task is to identify which are clinically important rather than plan treatment for every radiographic finding. Comparison with earlier images, a carefully chosen diagnostic injection or discussion with a musculoskeletal radiologist may be more useful than an indiscriminate sequence of tests.

Turn the findings into a working explanation

By the end of the assessment, I want a concise working explanation that connects the patient's symptom, the relevant structure, the mechanical setting and the biological context. For example, lateral hindfoot pain may arise in a collapsing foot because altered alignment changes local contact and tendon loading. That explanation is more useful than simply labelling the foot flat. Conversely, a visible deformity may be incidental if the pain is neurological or referred. The purpose of a differential diagnosis is to prevent the most conspicuous finding from closing the discussion too early.

I explain the degree of confidence in the diagnosis and what remains uncertain. A trial of treatment can contribute to assessment when its purpose is defined. Improvement with a support may suggest that controlling a particular load is helpful; temporary anaesthetic relief may support a suspected painful region. Neither response proves that an operation will succeed. The treatment response should be interpreted alongside the history, examination and imaging, and the working explanation should change when the evidence no longer supports it.

Assessment becomes a treatment decision

A working explanation joins the clinical findings to a meaningful functional goal.

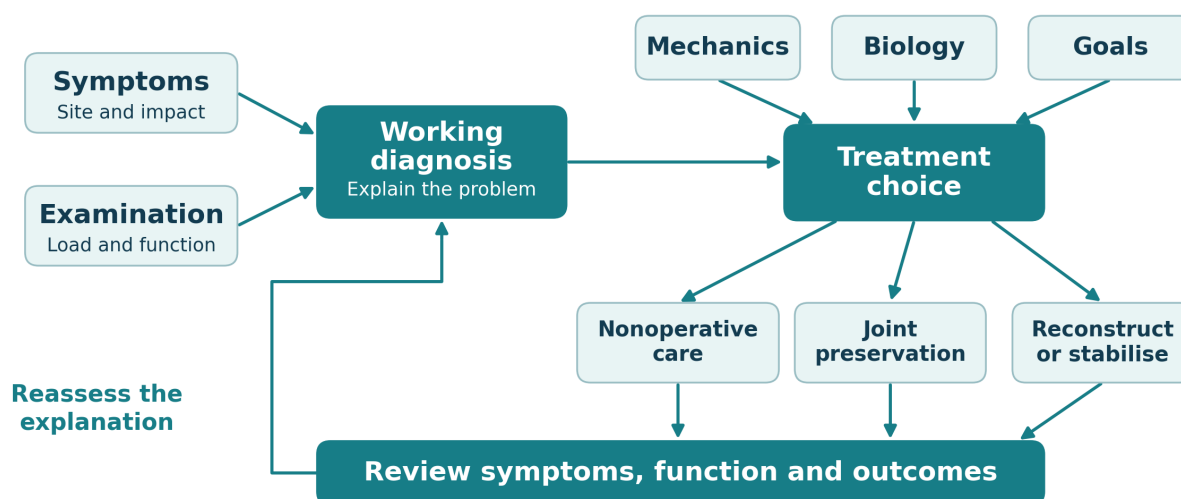


Figure 2.1. A working diagnosis connects symptoms and examination with the mechanical, biological and personal factors that guide treatment. Reviewing symptoms, function and outcomes can revise the original explanation. The treatment groups are complementary and may be combined.

Nonoperative treatment is a planned intervention

Nonoperative care deserves the same clarity of purpose as an operation. Footwear can provide room, cushioning or a change in the way the foot rolls forward. An orthosis may redistribute pressure or support a flexible deformity; a brace may control painful motion or instability. The device should address a specific problem and remain usable in the patient's daily life. A prescription that cannot fit inside practical footwear, or that creates a new pressure area, needs review. In a patient with impaired sensation, skin surveillance and specialist advice are especially important.

Physiotherapy should respond to the diagnosis and the stage of healing. Strength, balance, movement control and tolerance of loading are different goals, even when they are addressed within one programme. An irritable insertional Achilles tendon, a reconstructed ligament and a fused joint should not receive the same exercises. I ask what movement is desirable, what movement is restricted and what activity is being rebuilt. Progress should be judged against function and symptom response, with a plan for adjustment when improvement stalls.

Body weight, work demands, sleep, general conditioning and suitable pain relief may also influence the result. These discussions should be practical and respectful. They should offer achievable changes rather than present an idealised lifestyle as a condition of being heard. A defined review helps establish whether the treatment has been adequately tried and whether the original diagnosis remains plausible. Continuing nonoperative treatment is a legitimate choice when it provides acceptable function, even when surgery is technically possible.

Injections: explain the purpose and the evidence boundary

I distinguish an injection intended to clarify a pain source from one intended to reduce symptoms. The target, substance and expected duration of benefit should be explicit, together with infection risk, bleeding risk, medication considerations and any tissue-specific concerns. An injection that makes walking easier may create an opportunity for rehabilitation, but symptom relief does not demonstrate that cartilage or tendon has regenerated. Accurate placement does not compensate for a weak indication, and a disappointing response should prompt reconsideration rather than automatic repetition.

Evidence must be matched to the condition. The 2026 AAOS ankle osteoarthritis guideline advises against hyaluronic acid alone and against routine intra-articular PRP for symptomatic ankle osteoarthritis; it discusses a possible short-term benefit from hyaluronic acid combined with corticosteroid separately. These conclusions should not be represented as proof about every other joint or tendon condition. Where an intervention remains uncertain, the discussion should explain the uncertainty, alternatives and financial implications. The regional chapters examine the relevant choices in greater detail. [A7]

Prepare the biology before elective reconstruction

The decision to operate should include an assessment of what can be improved beforehand. Diabetes care, circulation, skin condition, active infection, anaemia, nutritional risk, frailty and relevant cardiopulmonary disease may alter the operation or the preparation it requires. A medication plan should be agreed with the appropriate clinicians, particularly for anticoagulants, diabetes medicines and immunomodulating treatment. The patient should not be left to decide independently which medicines to stop. Preoperative assessment becomes useful when it leads to an action, an agreed plan or a reconsidered decision. [A8]

Smoking is particularly important when bone healing is required. Ankle and hindfoot fusion information from the Royal National Orthopaedic Hospital emphasises cessation before surgery and throughout bone healing. I discuss cessation support early, rather than discovering the issue shortly before the operation. Nutrition and bone health also require attention when the history suggests a problem: unintended weight loss, a restricted diet, fragility fracture, steroid exposure or recurrent poor healing should lead to appropriate assessment. A supplement is not a substitute for understanding the cause of biological vulnerability. [A9]

Optimisation should be proportionate to the urgency and expected benefit. An elective operation may be delayed to improve a modifiable risk, while an open fracture or threatened limb cannot wait for ideal conditions. Risk factors are not a reason to withdraw thoughtful care. They are a reason to organise the right expertise, explain the likely consequences and sometimes choose a different strategy. The technically most ambitious reconstruction may not be the most useful treatment for a patient whose tissues or circumstances cannot support its recovery.

Choose the mechanical change, then examine its consequences

Joint preservation, osteotomy, tendon or ligament reconstruction, fusion and replacement change the limb in different ways. I first ask which change is needed: removal of an impingement, restoration of stability, redistribution of load, correction of deformity or elimination of painful joint motion. I then consider what that change asks of the remaining joints and muscles. An isolated procedure may fail to address a more proximal deformity or continuing imbalance. Equally, extending surgery to a painless adjacent joint can create a loss of function that the patient did not need.

The proposed operation should be tested against the patient's goals and recovery capacity. Is there a realistic path from the current problem to the desired activity? Can the patient manage the necessary protection, attend reviews and obtain help? Is the likely benefit worth the stiffness, scars, possible further procedures and recovery burden? These questions do not diminish surgical expertise. They make it relevant. A recommendation should survive scrutiny of the whole pathway, including what will happen if healing is delayed or the hoped-for improvement is incomplete.

Consent is a continuing clinical conversation

Shared decision-making requires a genuine comparison of reasonable options, including continuing current care or taking no immediate action. NICE encourages discussion of benefits, harms and consequences in a form the person can understand, with resources that help them prepare and participate. I find it useful to ask the patient to explain the proposed treatment back in their own words: what it is intended to improve, what it will change permanently and what recovery will demand. This is a check on my explanation rather than a test of the patient. [A10]

GMC guidance requires attention to what matters to the individual, relevant uncertainty and material risks. The conversation should cover realistic benefit, procedure-specific harm, serious complications, the consequences of declining treatment and reasonable alternatives. The effect of personal health and circumstances on these choices should be clear. Time to reflect, accessible information, an interpreter when needed and support chosen by the patient may make a substantial difference. A signed form records a decision; it cannot substitute for the dialogue that makes the decision informed. [A11]

I end the planning stage with an agreed next step and a way to review it. The record should make the diagnosis, proposed treatment, remaining uncertainty, preparation and expected follow-up intelligible to the patient and the team. New information can change the recommendation, and a patient can reconsider. The purpose is not to move every consultation towards an operation. It is to reach a defensible decision that connects the foot, the person and the care the service can reliably provide.

References for Chapter 2

[A1] British Orthopaedic Association. BOAST: Diagnosis and Management of Compartment Syndrome of the Extremities. Updated July 2025. [Read source](#)

[A2] British Orthopaedic Association. BOAST: Diagnosis and management of arterial injuries associated with musculoskeletal trauma. June 2026. [Read source](#)

[A3] NICE. Rheumatoid arthritis in adults: management. NG100, recommendations on referral, diagnosis and investigation. [Read source](#)

[A4] NICE. Diabetic foot problems: prevention and management. NG19, recommendations on active diabetic foot problems and Charcot arthropathy. [Read source](#)

[A5] American College of Radiology. ACR Appropriateness Criteria: Chronic Foot Pain. Current online narrative. [Read source](#)

[A6] American College of Radiology. ACR Appropriateness Criteria: Chronic Ankle Pain. Current online narrative. [Read source](#)

[A7] American Academy of Orthopaedic Surgeons. Management of Ankle Osteoarthritis: Evidence-Based Clinical Practice Guideline. Adopted 4 June 2026. [Read source](#)

[A8] Centre for Perioperative Care. Assessment, optimisation, shared decision making: perioperative preparation and medical optimisation. [Read source](#)

[A9] Royal National Orthopaedic Hospital. A Patient's Guide to Ankle and Hindfoot Arthrodesis / Ankle and Hindfoot Fusion. [Read source](#)

[A10] NICE. Shared decision making. NG197, recommendations. [Read source](#)

[A11] General Medical Council. Decision making and consent: The dialogue leading to a decision. [Read source](#)

CHAPTER 03

03 The ankle and hindfoot

The connected ankle and hindfoot

The ankle and hindfoot must be understood as a connected mechanical system. Pain may arise from cartilage, subchondral bone, impingement, ligament failure or a combination of these problems. A technically satisfactory operation on one joint may still disappoint if the deformity, instability or neighbouring painful joint has been overlooked. My aim is to restore a stable, plantigrade and useful foot, preserve worthwhile movement where possible, and obtain dependable pain relief when a joint can no longer be preserved.

This chapter examines the tibiotalar and subtalar articulations, their assessment, and the progression from conservative care to joint-preserving surgery, replacement or fusion. It also describes my preferred fibula-preserving ankle-fusion construct and my approach to subtalar fusion. These operative preferences are distinguished from comparative research evidence, particularly when discussing early weight bearing.

Functional anatomy and gait

Strictly, the hindfoot comprises the talus and calcaneus. The ankle is discussed alongside it because the tibia, fibula, talus and calcaneus function together during standing and walking. The distal tibia and fibula form the ankle mortise around the talar dome. The tibiotalar articulation is a modified hinge synovial joint. Its main movements are dorsiflexion and plantarflexion, accompanied by smaller coupled rotations rather than a perfectly fixed mechanical axis.

During stance, controlled ankle movement allows the tibia to advance over the foot. The plantarflexor muscle-tendon unit controls that progression and contributes to propulsion. Pain, equinus and stiffness can alter stride length and transfer demand to adjacent joints. The clinical objective is therefore broader than increasing an isolated range-of-motion measurement: movement should contribute to comfortable, efficient gait.

The subtalar articulation lies between the talus and calcaneus. Its oblique axis produces coupled inversion and eversion with components of rotation and translation. Together with the transverse tarsal joints, it helps the foot adapt to uneven ground and change from a flexible platform to a more effective lever during gait. Subtalar movement cannot be represented by a universal range of plus or minus five degrees; the observed range depends on the person, loading and measurement method. [H1]

The soft tissues determine how these bony relationships behave. The anterior talofibular ligament (ATFL), calcaneofibular ligament (CFL), deltoid complex, distal tibiofibular syndesmosis and capsule contribute to stability. Tendon function, calf tightness and proprioception also matter. A lax ankle with a talar tilt requires a different reconstruction from a stiff, well-aligned ankle, even when both show substantial cartilage loss.

Hindfoot: two linked articulations

Simplified bone relationships • lateral schematic • not to scale

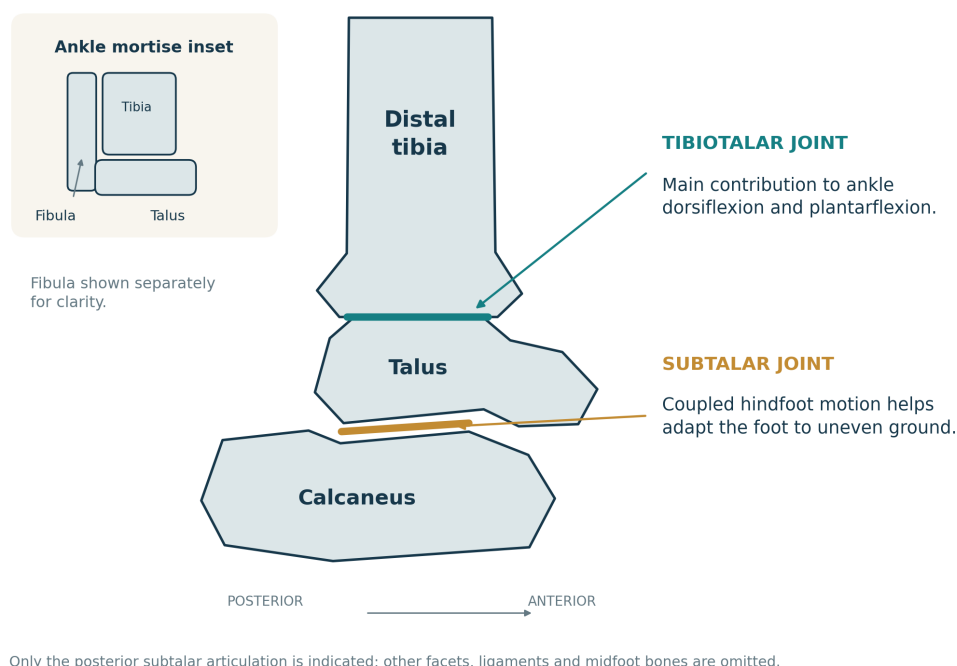


Figure 3.1. The ankle and hindfoot as connected articulations. This conceptual map distinguishes the tibiotalar joint from the subtalar joint; it is not a surgical anatomical atlas. The distal fibula contributes to the ankle mortise.

Establishing the pain generator

Assessment begins with the patient's experience. Where is the pain? Does it occur on level ground, on slopes, on uneven surfaces or at the end of a particular movement? Is there swelling, catching, giving way, rest pain or a previous injury? The history should establish walking tolerance, footwear limitations, occupation, recreational demands and what improvement would make treatment worthwhile.

Examination should include standing alignment, gait, the heel position and the relationship of the hindfoot to the forefoot. Record ankle motion with the hindfoot controlled, assess subtalar movement separately, and distinguish a fixed deformity from one that can be corrected manually. Examine the ATFL/CFL complex and deltoid function, the peroneal and tibialis posterior tendons, Achilles tightness, skin, scars, perfusion and sensation. A painful joint may coexist with neuropathy, vascular disease, tendon dysfunction or referred pain.

Weight-bearing ankle radiographs, including mortise and lateral views, provide the starting point for assessing joint space, osteophytes and alignment. Foot views and a hindfoot alignment view are added where the clinical question requires them. Imaging technique should be consistent when measuring correction over time. A study in my reference collection found better interobserver reliability for the long axial alignment view than for the hindfoot alignment view under its study conditions. [H2]

CT is useful for bone morphology, cysts, previous fusion, deformity and preoperative planning. Weight-bearing CT can help define deformity under load when available. MRI is particularly useful for focal osteochondral lesions, cartilage, marrow changes and associated soft-tissue pathology. A targeted image-guided local anaesthetic injection can support localisation when ankle and subtalar symptoms overlap, but its response must be interpreted alongside the examination and imaging.

Infection, active neuropathic arthropathy and a threatened soft-tissue envelope must be recognised before an elective reconstructive pathway is chosen. Smoking, diabetes control, vascular status, nutrition, bone quality, body weight and the practical ability to follow rehabilitation all influence risk. These factors are part of the treatment decision itself.

Ankle arthritis as a whole limb problem

Ankle arthritis frequently follows injury, but the history is rarely explained by cartilage wear alone. A previous fracture may leave a tilted plafond, a shortened or malrotated fibula, a damaged syndesmosis or a scarred soft-tissue envelope. Repeated instability may expose one side of the talar dome to abnormal loading. The visible narrowing on a radiograph is the final expression of these interacting problems. My task is to reconstruct the chain of events well enough to identify which parts remain modifiable.

The distinction between asymmetric and global arthritis is useful. Where substantial cartilage is preserved, a realignment procedure may redistribute loading and postpone joint-sacrificing surgery in a carefully selected patient. Supramalleolar osteotomy, sometimes combined with ligament reconstruction or a hindfoot correction, is therefore part of the specialist discussion. It requires a deformity that can be corrected, a worthwhile remaining joint and an explicit explanation of uncertainty. It is not a way of converting extensive cartilage loss into a normal ankle. [H24]

Pain is also influenced by what surrounds the joint. A patient with weakness, deconditioning and fear of falling may continue to walk poorly after an anatomically satisfactory reconstruction. A patient who must stand for a full working day faces different demands from someone whose goal is comfortable household mobility. I therefore make the functional target concrete before choosing an implant or fixation construct. The operation should solve a defined problem within a realistic plan for the person who will live with it.

Defining the pattern of disease

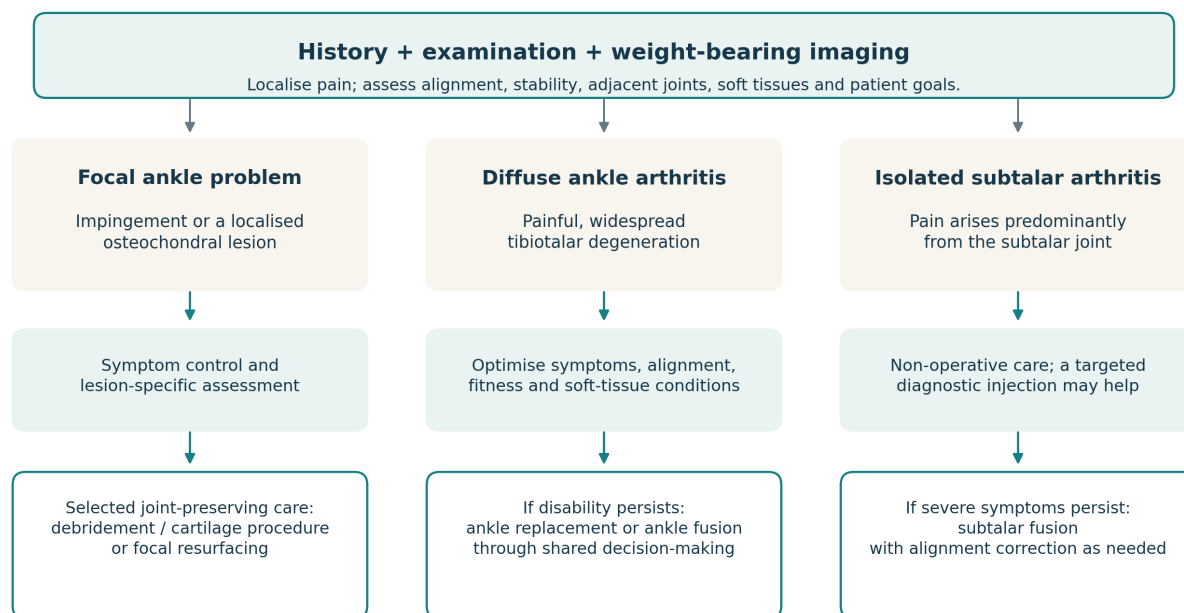
There is an important distinction between a local mechanical obstacle, a focal cartilage defect and widespread arthritis. An anterior osteophyte may restrict dorsiflexion while much of the joint remains serviceable. A contained talar osteochondral lesion may be painful in an otherwise preserved ankle. Diffuse joint-space loss, deformity and stiffness represent a different problem and require a different discussion.

The extent of cartilage loss contributes to the decision, but no single percentage defines a universal threshold for replacement or fusion. Symptoms, the distribution of degeneration, remaining movement, alignment, stability and the response to appropriate non-operative treatment must be considered together. A young age does

not by itself make a damaged joint suitable for preservation; advanced radiographic change does not mandate surgery in someone who is coping well.

Match treatment to the dominant problem

Individual assessment determines care; cartilage percentage alone does not select an operation.



Treatment options are selective, not a mandatory sequence. Evidence and suitability differ between procedures and biologic injections.

Figure 3.2. A framework for matching treatment to the dominant pathology. The branches support clinical reasoning; they are not automatic indications for surgery or a mandatory sequence of treatments.

Nonoperative care and injections

Conservative treatment should address the patient's main limitation. Activity modification, supportive footwear, a rocker sole, an appropriate brace or orthosis, and physiotherapy may reduce painful loading and improve confidence. Exercise should maintain useful strength and mobility without repeatedly provoking the joint. Weight management may be helpful where relevant, while analgesia and anti-inflammatory treatment require individual assessment of comorbidity and medication risk.

An intra-articular corticosteroid injection may provide temporary symptom relief and may also help identify the symptomatic joint when combined with local anaesthetic. It does not restore lost cartilage. The discussion should cover infection, a post-injection flare, skin or fat changes and transient hyperglycaemia in susceptible patients. Timing in relation to a proposed operation should follow the treating service's policy.

Platelet-rich plasma (PRP) and bone marrow aspirate concentrate (BMAC) are used in regenerative orthopaedic practice, but their indications and evidence must be described precisely. In a randomised placebo-controlled trial of 100 patients with ankle osteoarthritis, PRP did not improve symptoms and function more than saline at 26 weeks; the follow-up report found no advantage at 52 weeks. This does not answer

every question about PRP in every tissue, but it limits claims for established ankle arthritis. [H4, H5]

BMAC contains a variable mixture of cells and soluble factors; it is not a standardised preparation of purified stem cells. Its use alongside surgery for a focal osteochondral lesion is a different intervention from an isolated injection into an arthritic joint. A small retrospective case-control study of talar lesions found better MRI repair-tissue characteristics with BMAC added to marrow stimulation, with similar functional outcomes between groups. That evidence does not establish regeneration of a diffusely arthritic ankle. [H6]

My interest in the subchondral bone reflects its mechanical and biological role in the osteochondral unit. However, intraosseous or subchondral BMAC for subtalar arthritis remains an emerging approach. It should not be described as reliably strengthening the bone, sealing cartilage or preventing fusion. Evidence from the knee or from focal talar lesions cannot simply be transferred to the subtalar joint. [H6, H22]

The 2026 American Academy of Orthopaedic Surgeons guideline adds an ankle-specific perspective: it recommends against hyaluronic acid alone and advises against routine PRP for symptomatic ankle osteoarthritis. A possible short-term benefit from combining hyaluronic acid with corticosteroid is qualified by the limited evidence and incomplete treatment protocols. Corticosteroid remains an option for short-term symptom relief. These distinctions support an honest biological treatment discussion: symptom improvement, cartilage restoration and avoidance of future surgery are separate claims and require separate evidence. [H23]

Treatment	Intended role	Limit relevant to counselling
Footwear, orthosis or brace	Modify loading and support stability	Does not reverse structural arthritis
Physiotherapy and exercise	Maintain strength, balance and useful movement	Programme must fit the pathology and symptoms
Corticosteroid injection	Temporary symptom control; sometimes diagnostic support	Duration varies; cartilage is not regenerated
PRP for ankle osteoarthritis	Proposed biological symptom treatment	Placebo-controlled ankle evidence has not shown benefit [H4, H5]
BMAC with cartilage surgery	Investigational adjunct in selected focal lesions	Evidence is limited and cannot be generalised to diffuse subtalar arthritis [H6]

Impingement and focal cartilage lesions

Anterior or posterior ankle impingement may result from osteophytes, soft-tissue scarring or other local pathology. When symptoms are convincingly linked to a mechanical block and the remaining joint is sufficiently preserved, arthroscopic or open debridement with cheilectomy or osteophyte excision may improve movement and pain. The location of the pain, the movement that reproduces it and the imaging must agree before the spur is treated as the principal problem.

Debridement cannot compensate for widespread loss of the bearing surface. The patient should understand that removing an impinging spur may improve a particular painful movement without resolving the entire arthritic process. Instability or malalignment that produced the overload may need to be treated at the same time or as part of a staged plan.

An osteochondral lesion of the talus involves cartilage and, to a variable extent, its supporting bone. Management depends on the lesion's size, depth, containment, location, cystic change, stability and previous treatment. Symptoms and the wider mechanical environment remain central. A period of activity modification, rehabilitation and selective offloading is reasonable in suitable cases; an unstable fragment or persistent mechanical symptoms may change that approach.

Arthroscopic debridement and bone marrow stimulation, commonly called microfracture, are established options for selected small, contained lesions. Preparation removes unstable tissue and creates controlled access to marrow elements beneath the defect. The repair is predominantly fibrocartilaginous rather than a recreation of normal hyaline cartilage. Larger, deep, uncontained or previously treated lesions may require other reconstructive strategies, such as fragment fixation, bone grafting, osteochondral grafting or specialist cartilage-restoration procedures. Size cut-offs vary and should be used as selection aids rather than absolute biological boundaries. [H7, H18]

Rehabilitation after cartilage surgery must reflect the defect and any associated procedure. A loading programme used after a rigid fusion should not automatically be applied to microfracture, a graft or an osteotomy. Likewise, evidence for earlier loading in selected microfracture patients does not establish that every talar lesion can be loaded immediately. [H7]

The role and limits of ankle arthroscopy

Arthroscopy is a method of access. Its value comes from selecting a problem that can be treated through that access: an impinging lesion, a loose body, selected osteochondral pathology or intra-articular disease accompanying instability. Small skin incisions do not make the intervention biologically trivial. The superficial nerves, articular cartilage and soft tissues remain vulnerable, and consent should include infection, nerve symptoms, persistent pain and the possibility of additional surgery. [H25]

The procedure should have a clear purpose before the patient enters theatre. In a patient whose principal symptom is anterior pain at the end of dorsiflexion, removal of a local impingement may be meaningful. In a patient with pain throughout the arc of

movement and widespread joint destruction, debridement is unlikely to fulfil the same expectation. A minimally invasive approach is helpful only when it can achieve the necessary treatment.

Arthroscopic findings can refine the assessment, but they should be interpreted within the standing alignment and functional examination already established. An osteochondral lesion in an unstable varus ankle is not just a cartilage problem. Treating the lesion while leaving the cause of repeated overload unresolved risks an incomplete result. Conversely, each additional procedure adds rehabilitation demands and should have a reason that can be explained to the patient.

Chronic ankle instability

Recurrent giving way can reflect mechanical ligament insufficiency, impaired neuromuscular control, or both. A patient may also describe giving way when pain inhibits the muscles around an otherwise stable joint. I ask whether the ankle repeatedly turns in, whether a sudden sharp pain precedes the episode, and whether there is loss of confidence on irregular ground. This distinction prevents an operation for laxity from being offered as a universal treatment for every unstable-feeling ankle.

The assessment includes the anterior drawer and talar tilt, standing heel alignment, first-ray position, generalised laxity and the peroneal tendons. MRI is useful when associated osteochondral injury, tendon disease or impingement may explain persistent symptoms. Focused rehabilitation should develop balance, strength, proprioception and activity-specific control, with bracing where useful. Persistent symptomatic mechanical instability despite this treatment may justify anatomical repair, commonly a Broström-Gould procedure, or reconstruction when the remaining tissue cannot support a durable repair. [H26]

Where there is a cavovarus foot, I consider whether the lateral ligament has been asked to resist an abnormal load over many years. A ligament repair cannot be expected to overcome every fixed deformity. Alignment correction and ligament surgery may therefore need to be combined. The principle is to address the reason the ligament remains overloaded, while preserving useful motion and avoiding unnecessary procedures.

The postoperative plan must protect a healing ligament while rebuilding control. Return to sport depends on strength, balance, confidence and the ability to perform the required movements safely, not merely on an elapsed number of weeks. Pain, swelling and repeated giving way after treatment prompt reassessment for associated pathology or a persistent mechanical problem.

Patient specific focal talar resurfacing

Focal metallic resurfacing offers a further option for carefully selected patients whose lesion is localised and whose remaining ankle joint is reasonably preserved. Episealer Talus is an example of a patient-specific system. CT and MRI define the bone and cartilage geometry, support implant design, and guide production of customised instruments. This is a focal resurfacing operation rather than a total ankle replacement. [H8]

Selection requires assessment of the opposing tibial cartilage, lesion dimensions, surrounding bone, alignment and stability. Significant generalised degeneration makes focal treatment less attractive. The procedure may be considered in selected persistent lesions, including some that have failed previous treatment, but the availability of an individualised implant does not remove the need for careful indication and surgical access planning.

A prospective report published in 2026 described 20 treated patients, with 17 completing 24-month follow-up. Pain and functional scores improved; three complications were reported, including one failure requiring revision. These results are encouraging, but the uncontrolled sample and limited follow-up do not establish long-term durability or superiority over other treatments. The possible consequences of failure and the next reconstructive option belong in the initial discussion. [H9]

Choosing ankle replacement or fusion

When pain and disability from end-stage tibiotalar arthritis remain unacceptable despite appropriate non-operative care, total ankle replacement and ankle arthrodesis are the principal definitive options. Both should be available within a foot and ankle service or referral network. The choice is a shared decision informed by deformity, ligament competence, bone stock, soft tissues, adjacent joints, activity demands and the patient's priorities. [H3]

Replacement aims to relieve pain while retaining movement at the ankle. Fusion aims to relieve pain by eliminating movement at the diseased articulation. A well-positioned fusion can provide a useful limb, but its success depends on union and alignment. Replacement retains an articulation that requires surveillance and may eventually require further surgery. Neither operation guarantees complete pain relief or restoration of a normal ankle.

Chronological age is only one consideration. Implant longevity and the possibility of revision matter, particularly in a younger patient with many years of expected loading. Nevertheless, replacement cannot sensibly be timed on the assumption that it will certainly last for the remainder of a person's life. Conversely, fusion is not appropriate "at any stage" merely because it has no bearing surface to wear out. The indication remains disabling disease and an acceptable balance of benefit and risk.

The choice should also be made in a service able to provide both options and manage their complications. The BOA and BOFAS standards support ankle arthritis networks, documented shared decisions and registry submission for replacement. They specify clinical and radiographic follow-up for at least two years after primary replacement, with access to direct review throughout implant life; revision replacements require annual review. Fusion should be followed until clinical or radiological evidence of union. Follow-up is part of the treatment, not an optional addition once the wound has healed. [H3]

Consideration	Total ankle replacement	Ankle fusion
Main mechanical effect	Retains some tibiotalar movement	Abolishes tibiotalar movement
Important requirements	Suitable bone stock, soft tissues and correctable alignment and stability	Viable bone, suitable alignment and a construct capable of supporting union
Characteristic concerns	Wound problems, impingement, fracture, loosening, cysts, wear and revision	Nonunion, malunion, hardware symptoms and altered adjacent-joint demands
Adjacent-joint disease	Motion preservation may be valuable, but other pain generators require treatment	Pre-existing subtalar or midfoot disease may limit the result
Long-term planning	Implant surveillance and a credible revision or salvage plan	Surveillance for painful nonunion, malalignment and adjacent-joint symptoms

Which joint loses or retains motion?

Conceptual comparison of the principal articulations • implant design and fixation are not depicted

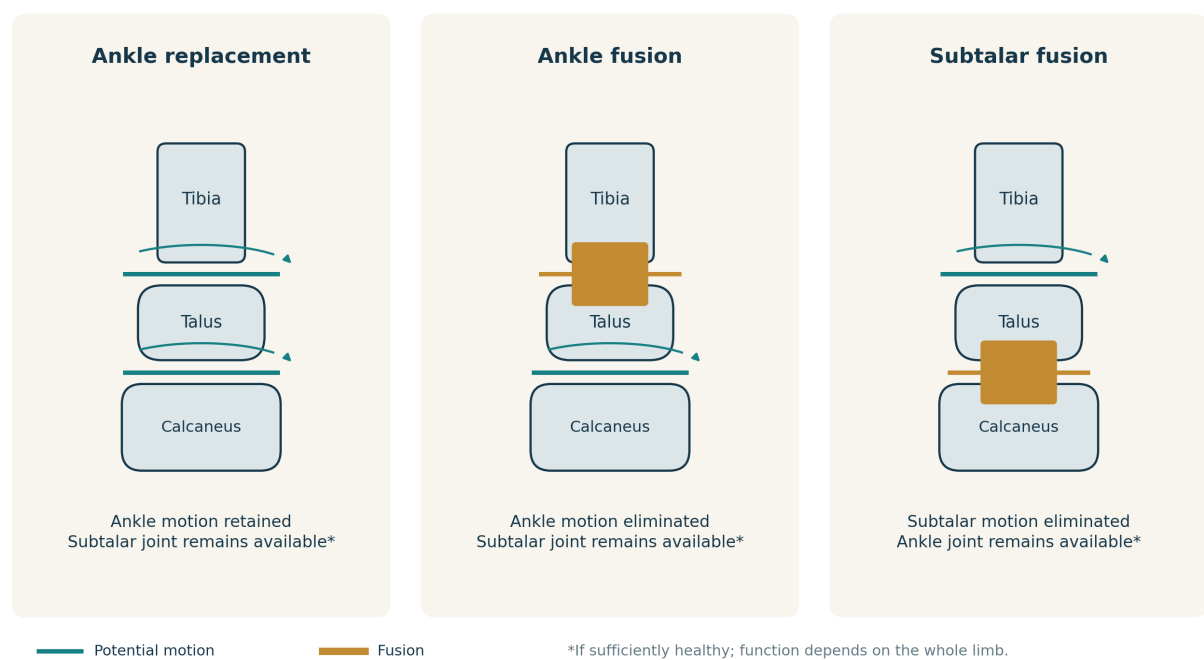


Figure 3.3. Different operations address different articulations. Ankle replacement preserves an artificial tibiotalar articulation; ankle fusion removes tibiotalar motion; isolated subtalar fusion removes subtalar motion while leaving the ankle unfused. These are conceptual diagrams, not implant or screw-placement plans.

Comparative outcomes and clinical judgement

The TARVA trial randomised 303 patients aged 50 to 85 years who were considered suitable for either replacement or fusion. Both groups improved. At 52 weeks, the adjusted difference in the primary walking/standing outcome was -5.6 points, with a 95% confidence interval from -12.5 to 1.4 and $p = 0.12$. The overall comparison did not demonstrate statistically significant superiority of replacement; it did not prove that the two procedures are equivalent. A post hoc fixed-bearing subgroup favoured replacement, but that analysis should be interpreted as exploratory. The complications also differed: wound and nerve problems were more frequent after replacement, while symptomatic nonunion occurred in 7.1% of fusion patients. [H10]

In my practice, there are satisfied and less satisfied patients in both categories. My early single-surgeon manuscript includes nine ankle fusions, eleven primary replacements and three revision replacements. It did not detect statistically significant between-group differences in change scores at the early review, approximately two weeks after surgery. The small groups, incomplete paired observations and short follow-up prevent conclusions about equivalence, durable function or implant survival. The study is best understood as preliminary outcomes work. [H19]

This distinction matters. A patient's early wound review cannot answer whether the reconstruction will remain comfortable over ten years. Comparative assessment should include validated patient-reported outcomes, complications, further operations, radiographic findings and the activities that matter to the patient. Revision replacement should also be analysed separately from uncomplicated primary surgery.

Long-term counselling requires realistic survival data. A UK study linking the National Joint Registry with NHS Digital included 5,562 primary replacements and reported survivorship of 90.2% at five years and 86.2% at ten years. The ten-year estimate rested on substantially fewer patients at that interval. These are historical population estimates across implants and patients, not a personalised prediction or a statement that every retained implant functions well. The study also demonstrated why linkage matters: relying on registry entries alone missed some failures. [H11]

Infinity and Prophecy

Infinity is a fixed-bearing total ankle system, generally implanted through an anterior approach. The construct includes a metal tibial tray, a polyethylene bearing fixed to that tray, and a metal talar component. Precise bone preparation, component positioning, ligament balancing and correction of associated deformity are as important as the choice of implant.

The original Infinity designs and subsequent versions should not be described as having identical surface treatments. The Infinity with Adaptis guide in my reference collection describes a porous metal surface produced by direct metal laser sintering, with titanium-alloy tibial and cobalt-chromium talar components. Coating, fixation method and permitted component combinations should always be checked against the specific implant generation and applicable instructions for use. [H12]

Prophecy is the patient-specific planning and instrumentation system. It uses a prescribed CT acquisition and preoperative planning to produce guides intended to assist alignment and bone preparation. It is not a separate replacement implant and is not restricted solely to complex cases. Custom guides do not remove the need to confirm their fit, assess the plan intraoperatively and retain the ability to use standard instrumentation when necessary. [H13]

I regard these developments as useful additions to the treatment of ankle arthritis when applied to an appropriate patient. Published evidence is encouraging: a prospective multicentre Infinity cohort of 503 implants reported 98.8% survivorship at two years. This supports the system's early performance, but an observational implant series cannot establish superiority over fusion or guarantee a lifetime result. [H14]

Ankle fusion principles

Arthrodesis requires adequate joint preparation, viable opposing bone surfaces, appropriate alignment, compression and stable fixation. Cartilage must be removed while preserving useful bone. The bone surfaces are prepared to support healing, and defects or compromised biology may require grafting or other measures. Fixation can involve screws, plates, a nail or external fixation according to the problem; arthroscopic fusion is an option in selected circumstances.

The intended result is a plantigrade foot with a clinically appropriate heel position and rotation. Pre-existing deformity, limb alignment and the opposite limb help inform this position. An isolated tibiotalar fusion preserves the subtalar joint; a tibiototalcalcaneal fusion crosses both joints and has a different indication and functional consequence. The two should not be presented as interchangeable operations.

Smoking, poor perfusion, neuropathy, uncontrolled diabetes, infection, compromised bone and difficulty following postoperative instructions may increase risk. A rigid-looking construct does not abolish biological requirements for union. Painful nonunion, malunion, deep infection and symptomatic hardware remain important consent issues.

My preferred fibula-preserving construct

My preferred open technique uses lateral and anterior access. A fibular osteotomy permits the distal segment to be temporarily reflected or rotated by approximately 90 degrees to improve exposure. After cartilage removal and preparation of the fusion surfaces, I restore the fibula to its anatomical relationship and secure the reconstruction using a lateral tubular plate together with an anterior plate. The fibula is not left permanently rotated through 90 degrees.

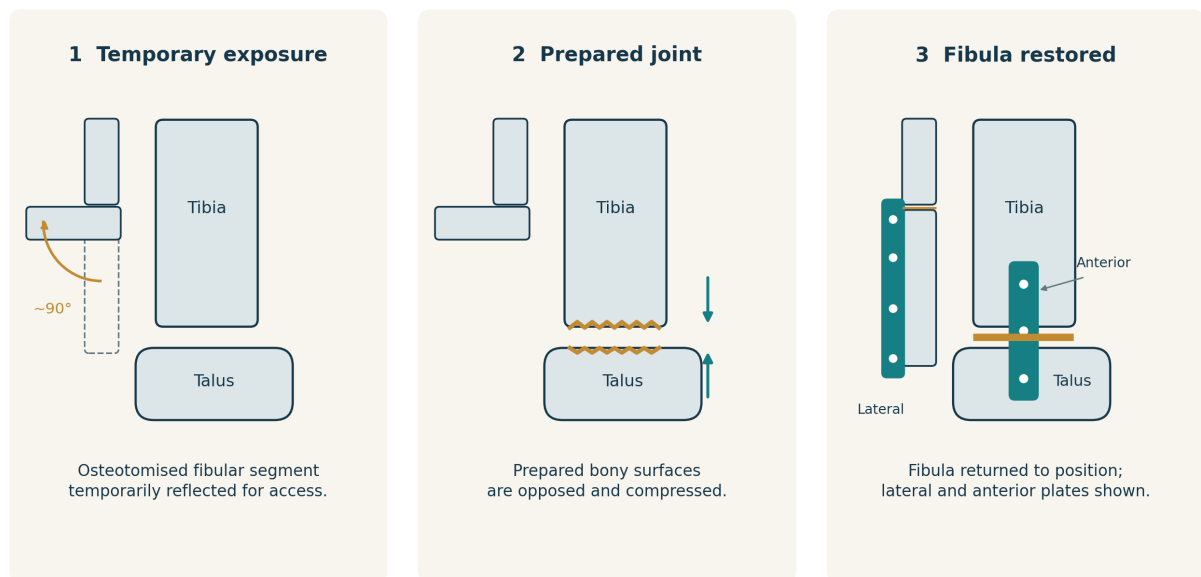
The purpose is to preserve the shape and lateral support of the ankle while creating a stable, compressed fusion. The restored fibula contributes to containment of the talus within the mortise, and the plates resist movement across the prepared articulation. These features aim to limit micromotion; they do not mean that movement is mechanically impossible or that union has already occurred. This is my operative preference, rather than evidence that every dual-plate construct supports the same loading programme. [H20]

Related published work using combined transfibular and anterior approaches reported partial weight bearing from two weeks and full weight bearing from four weeks. It provides context for earlier mobilisation after stable fixation, but it is not a validation of my exact construct or a universal instruction for immediate full loading. [H15]

Preserving the fibula and malleolar architecture may retain options if conversion of fusion to replacement is later considered. Such conversion has been described in selected patients, including those with painful failed fusion or symptomatic adjacent-joint disease. It is technically demanding and depends on bone stock, alignment, fibular support, soft tissues and neuromuscular function. A preserved fibula improves the anatomical starting point but does not make fusion predictably reversible. I have not needed to perform this conversion in my clinical practice. [H16]

Author's fibula-preserving ankle fusion concept

Three schematic stages • based on Mr Bakhshayesh's dictated operative description



The fibula is restored, not left rotated. Plate symbols show the concept only; their position is not a surgical template.

This author-specific construct does not by itself establish a universal immediate or two-week weight-bearing protocol.

Figure 3.4. The author's fibula-preserving ankle-fusion concept. Temporary fibular reflection allows access; the fibula is restored before final fixation. Plate positions are represented conceptually and do not prescribe screw trajectories or replace operative planning.

Subtalar arthritis and fusion

Subtalar arthritis often causes hindfoot pain during uneven-ground walking, inversion or eversion. It may follow a calcaneal or talar injury, occur with deformity or coalition, or form part of a wider arthritic process. The ankle, talonavicular and calcaneocuboid joints should be assessed before attributing all hindfoot symptoms to the subtalar articulation.

Non-operative management follows the principles already described, with particular attention to supportive footwear and bracing that limits painful hindfoot movement. A targeted injection may help with symptoms and localisation. Arthroscopic debridement

can be useful for selected focal pathology, loose bodies or impingement; its role is limited when the joint has diffuse end-stage degeneration. Neither youth nor an interest in biologics alone establishes an indication for repeated injections or debridement.

Persistent disabling symptoms from isolated end-stage subtalar arthritis can be treated with subtalar arthrodesis. The operation must also correct relevant malalignment. When several joints are diseased, or when a substantial deformity requires broader reconstruction, an isolated fusion may be insufficient. The plan should identify each joint being treated and explain why.

My approach commonly uses the sinus tarsi exposure. The joint is prepared by removing cartilage and creating viable bony surfaces. Controlled drilling or feathering of the subchondral surface exposes cancellous bone and supports fusion biology while avoiding unnecessary damage. The practical aim is a healing environment with close bone contact, rather than uncontrolled cracking of the bones.

I use partially threaded 6.5 mm cancellous or cannulated compression screws in appropriate cases. Implant selection, screw number, direction and purchase depend on anatomy, bone quality and the chosen system. Compression must be achieved across the intended fusion site without compromising neighbouring structures. Bone graft may be required where there is a defect or a particular biological concern.

My related manuscript on subtalar and medial column fusion describes a ten-patient early series of combined reconstruction for progressive collapsing foot deformity. It supports the description of my operative approach, but its approximately six-week review and absence of a reported radiographic union outcome do not establish the success rate of isolated subtalar fusion. [H21]

Selective double and triple hindfoot fusion

Hindfoot fusion is a description of a family of operations. An isolated subtalar fusion retains a different movement envelope from a reconstruction that includes the talonavicular joint. Triple arthrodesis combines subtalar, talonavicular and calcaneocuboid fusion. The term double fusion can refer to different combinations, so the operative plan and consent should name the joints explicitly. [H27]

In a rigid painful collapsing foot, selective arthrodesis may both relieve joint pain and restore the heel and forefoot to a plantigrade relationship. Healthy joints should be retained when they are not needed for correction or stability. The calcaneocuboid joint does not automatically require fusion merely because the subtalar and talonavicular joints are treated. Equally, retaining a severely diseased joint for the sake of preserving movement may leave an important pain generator behind.

I assess forefoot position after correcting the hindfoot because correction can expose a residual supination or instability of the medial column. A foot that looks better from behind may still load poorly at the front. The reconstruction is complete only when the heel, arch and forefoot make sense together. This is where hindfoot surgery meets the midfoot principles in the next chapter.

Patients should understand the practical consequences of the intended stiffness. Comfortable level-ground walking may improve greatly, while uneven ground, slopes

and certain footwear remain demanding. An ankle that already has substantial arthritis also changes the planning. The discussion should include how much movement will remain, where it will occur and what further treatment could be required if adjacent disease becomes symptomatic.

Rehabilitation and the meaning of healing

Postoperative care should be written down as a procedure-specific plan. Wound healing, bone union, implant integration and functional recovery are different processes. A clean, healed incision at two weeks does not demonstrate that an arthrodesis has united. Equally, a patient who is walking in a boot has not necessarily recovered strength, balance or tolerance of prolonged activity.

In my practice, patients commonly receive a backslab for the first two weeks, with elevation, wound protection and an individual thrombosis-prevention plan. Following selected stable ankle fusions, I may permit earlier loading, sometimes immediately, or introduce full weight bearing in a protective boot once the wound has healed at the two-week review. That decision depends on the construct, alignment, bone quality, biological risk and associated procedures. It is a selected-patient protocol rather than a default instruction for every ankle fusion.

For subtalar fusion, my protocol is non-weight bearing for the first two weeks, followed by wound review and, in suitable patients, full weight bearing in a boot. Progression must be modified where fixation, grafting, additional reconstruction, neuropathy, wound problems or patient factors require longer protection. The practical ability to use crutches, negotiate stairs and avoid falls must also be considered.

Earlier-loading evidence is developing. A 2026 systematic review of isolated primary subtalar fusion did not find worse union or complication outcomes with weight bearing within two weeks, but the quality and comparability of the included evidence were limited. Its findings should not be extended automatically to revision surgery, combined fusions or high-risk patients. [H17]

Six to twelve weeks is a useful period for reassessing early healing after fusion, with clinical examination and radiographs. Some patients need longer, and CT may be helpful when union remains uncertain and the answer would change management. Persistent focal pain, increasing swelling or loss of correction warrants reassessment rather than progression according to the calendar alone.

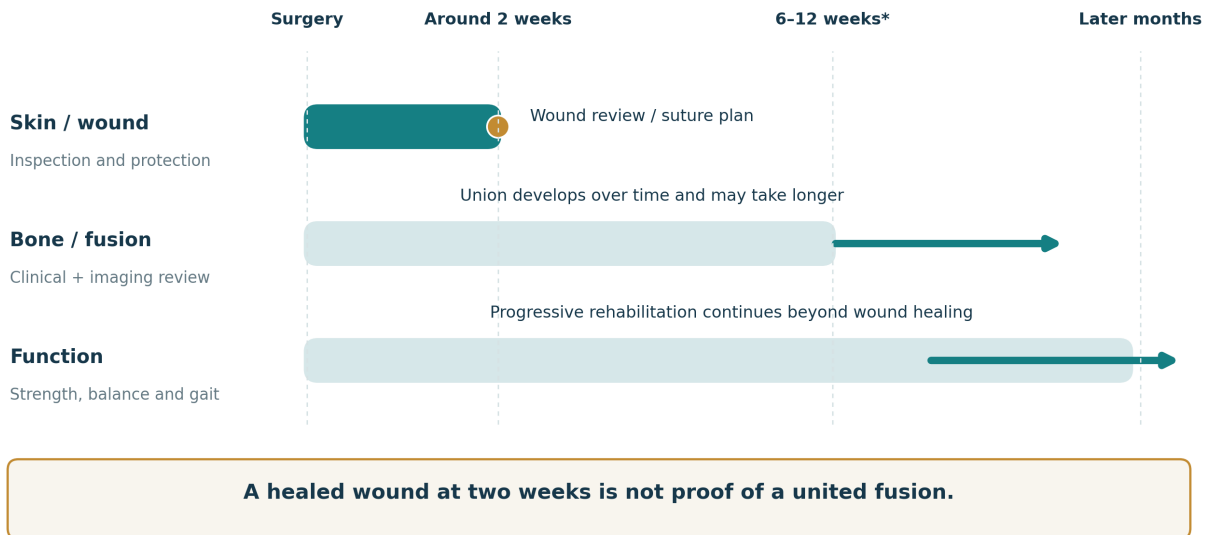
Following ankle replacement, rehabilitation must account for wound healing, implant fixation and any accompanying osteotomy or ligament procedure. The intended process is integration of the components with the supporting bone while retaining joint movement. It should not be described as fusion of the replaced ankle. Swelling, strength and walking endurance can continue to improve over several months after any of these operations.

Physiotherapy should address gait, balance, muscle strength and the movement of joints that have not been fused. Patients need clear advice about boot use, walking aids, return to work and driving. Increasing wound redness or drainage, fever, an acutely

cold or numb foot, or rapidly escalating pain needs prompt assessment; chest pain or sudden breathlessness requires emergency attention.

Recovery has more than one milestone

Illustrative phases after hindfoot surgery • timing and loading are prescribed for the individual patient



Weight-bearing is a separate decision: construct stability, bone quality, soft tissues and patient factors all matter.

*A review window, not a guaranteed union date. Ankle replacement requires implant and wound surveillance rather than fusion union.

Timeline spacing is qualitative. Early loading in a boot is selective and must follow the treating surgeon's protocol.

Figure 3.5. Recovery milestones represent different biological and functional processes. The two-week visit is principally a wound and rehabilitation review. Permission to load remains an individual clinical decision; six to twelve weeks is an assessment interval rather than a guarantee of union or complete recovery.

The standard I seek

The operation is only one part of treatment. I want the patient to understand why a particular joint is painful, what the proposed procedure can achieve and what it will leave unchanged. The quality of the decision depends on matching the operation to the entire limb and to the person's life.

A useful review records pain, walking distance, footwear, confidence on uneven surfaces and meaningful daily activities, alongside a consistent patient-reported outcome measure such as the Manchester-Oxford Foot Questionnaire. Radiographic union and implant retention are important, but they do not replace the patient's account of function. My guiding principle is to preserve movement when it remains useful, create stability where disease makes movement painful, and support the patient through the full course of recovery.

References for Chapter 3

[H1] Peña Fernández M, et al. Centre of Rotation of the Human Subtalar Joint Using Weight-Bearing Clinical Computed Tomography. Scientific Reports. 2020. doi:10.1038/s41598-020-57912-z. [Read source](#)

[H2] Reilingh ML, Beimers L, Tuijthof GJM, et al. Measuring hindfoot alignment radiographically: the long axial view is more reliable than the hindfoot alignment view. Skeletal Radiology. 2010;39:1103-1108. doi:10.1007/s00256-009-0857-9. [Read source](#)

[H3] British Orthopaedic Association and British Orthopaedic Foot and Ankle Society. Speciality Standards: Management of End Stage Ankle Arthritis. April 2025. [Read source](#)

[H4] Paget LDA, Reurink G, de Vos RJ, et al. Effect of Platelet-Rich Plasma Injections vs Placebo on Ankle Symptoms and Function in Patients With Ankle Osteoarthritis: A Randomized Clinical Trial. *JAMA*. 2021;326:1595-1605. doi:10.1001/jama.2021.16602. [Read source](#)

[H5] Paget LDA, et al. Platelet-Rich Plasma Injections for the Treatment of Ankle Osteoarthritis. *American Journal of Sports Medicine*. 2023. doi:10.1177/03635465231182438. [Read source](#)

[H6] Hannon CP, Ross KA, Murawski CD, et al. Arthroscopic Bone Marrow Stimulation and Concentrated Bone Marrow Aspirate for Osteochondral Lesions of the Talus: A Case-Control Study of Functional and Magnetic Resonance Observation of Cartilage Repair Tissue Outcomes. *Arthroscopy*. 2016;32:339-347. doi:10.1016/j.arthro.2015.07.012. [Read source](#)

[H7] Deal JB Jr, et al. Early vs Delayed Weightbearing After Microfracture of Osteochondral Lesions of the Talus: A Prospective Randomized Trial. *Foot & Ankle Orthopaedics*. 2019;4(2):2473011419838832. doi:10.1177/2473011419838832. [Read source](#)

[H8] Mosca M, Caravelli S, Di Ponte M, et al. Surgical technique of an innovative patient-specific metal implant for talar osteochondral lesions. *Journal of Experimental Orthopaedics*. 2025;12:e70085. doi:10.1002/jeo2.70085. [Read source](#)

[H9] Mosca M, Di Ponte M, Cassanelli E, et al. Patient-specific talar resurfacing improves pain and function at 24 months in osteochondral lesions of the talus. *Knee Surgery Sports Traumatology Arthroscopy*. Published online 13 July 2026. doi:10.1002/ksa.70527. [Read source](#)

[H10] Goldberg AJ, Chowdhury K, Bordea E, et al. Total ankle replacement versus ankle arthrodesis for patients aged 50-85 years with end-stage ankle osteoarthritis: the TARVA RCT. *Health Technology Assessment*. 2023;27(5). doi:10.3310/PTYJ1146. [Read source](#)

[H11] Jennison T, Ukoumunne O, Lamb S, Sharpe I, Goldberg AJ. How long do ankle arthroplasties last? A data linkage study using the National Joint Registry and NHS Digital. *Bone & Joint Journal*. 2023;105-B:301-306. doi:10.1302/0301-620X.105B3.BJJ-2022-0806.R1. [Read source](#)

[H12] Wright Medical / Stryker. Prophecy Infinity with Adaptis Technology Preoperative Navigation Guides: Surgical Technique. Manufacturer guide in the author's reference collection; product information, indications and implant specifications. Current system information. [Read source](#)

[H13] Stryker. Prophecy surgical planning and patient-specific instrumentation. Manufacturer product information. Accessed 14 October 2026. [Read source](#)

[H14] Townshend DN, et al. Two to Five-Year Outcomes of Total Ankle Arthroplasty with the Infinity Fixed-Bearing Implant. *Journal of Bone and Joint Surgery American*. 2023. doi:10.2106/JBJS.22.01294. [Read source](#)

[H15] Park JJ, Son WS, Woo IH, Park CH. Combined Transfibular and Anterior Approaches Increase Union Rate and Decrease Non-Weight-Bearing Periods in Ankle Arthrodesis. *Journal of Clinical Medicine*. 2021;10:5915. doi:10.3390/jcm10245915. [Read source](#)

[H16] Lian G, Ip W, Hankins A, Guillen M, Parise C. Midterm Outcomes Following Conversion of Failed Ankle Arthrodesis to Total Ankle Arthroplasty, Including Patients With a Deficient Fibula. *Foot & Ankle Orthopaedics*. 2025;10(3):24730114251351636. doi:10.1177/24730114251351636. [Read source](#)

[H17] Chan G, Gregg R, Christidis P, et al. Effect of early compared with late weightbearing on the outcomes of subtalar joint arthrodesis: a systematic review and meta-analysis of single proportions. *Bone & Joint Journal*. 2026;108-B(3):399-406. doi:10.1302/0301-620X.108B3.BJJ-2025-0461.R1. [Read source](#)

[H18] British Orthopaedic Foot and Ankle Society. Hyperbook: Talar Osteochondral Lesions. Clinical educational reference. Accessed 14 October 2026. [Read source](#)

[H19] Author's research archive. Primary Total Ankle Replacement, Revision Ankle Arthroplasty, and Ankle Fusion: Early Outcomes from a Single-Surgeon Retrospective Series. File: SingleSurgeon_AnkleOutcomes_Manuscript_REVISED.docx. Unpublished working manuscript; approximately two-week outcomes. Cited in the author-supplied chapter dated 14 October 2026.

[H20] Bakhshayesh P. Operative technique and rehabilitation preferences dictated for this chapter, 14 October 2026. Related archive: Ankle_Fusion_Techniques_Review_FootAnkleIntl.docx; working manuscript, publication status unverified. The dictated personal technique is not presented as a validated comparative trial.

[H21] Author's research archive. PCFD_Subtalar_MedialColumn_CaseSeries_FINAL.docx. Early ten-patient combined subtalar and medial column reconstruction series; unpublished working manuscript. Cited in the author-supplied chapter dated 14 October 2026.

[H22] Bakhshayesh P. Bone Marrow Aspirate Concentrate for Sub-Chondral Bone Applications in Osteochondral Healing: A Systematic Review. File: Systematic Review BMAC.docx. Working manuscript; publication status unverified. Cited for the author's research interest rather than as proof of efficacy in subtalar arthritis.

[H23] American Academy of Orthopaedic Surgeons. Management of Ankle Osteoarthritis Evidence-Based Clinical Practice Guideline. 2026. [Read source](#)

[H24] British Orthopaedic Foot & Ankle Society. The role of osteotomies in the management of ankle osteoarthritis. BOFAS Hyperbook. [Read source](#)

[H25] British Orthopaedic Foot & Ankle Society. Ankle impingement. BOFAS Hyperbook. [Read source](#)

[H26] British Orthopaedic Foot & Ankle Society. Ankle instability. BOFAS Hyperbook. [Read source](#)

[H27] British Orthopaedic Foot & Ankle Society. Subtalar arthritis and pes planus. BOFAS Hyperbook. [Read source](#)

CHAPTER 04

04 Midfoot conditions and reconstruction

Understanding the midfoot

The midfoot is a load-bearing structure whose function depends on its relationship with the whole lower limb. A painful joint cannot be understood fully without examining the position of the hindfoot, the shape of the arch, the balance of the tendons and the way the patient stands and walks. My approach is therefore to assess the patient, the alignment and the biology of healing together. The objective is a comfortable, stable, plantigrade foot that allows the patient to move with confidence.

Midfoot conditions may develop after an acute injury, repeated loading, progressive deformity or inflammatory disease. Several processes often coexist. A previously injured Lisfranc complex may become arthritic; a collapsing arch may increase stress across the naviculocuneiform joints; and poor bone quality may complicate both the original problem and its reconstruction. Treatment must identify which process is responsible for pain and which is responsible for instability or deformity.

This chapter considers traumatic and degenerative midfoot conditions, their assessment, non-operative treatment, selective fusion and revision reconstruction. It also describes my preference for sound joint preparation, correction, compression and plate protection. Where I describe my own grafting or postoperative approach, it represents a clinical practice applied to selected patients. It should be interpreted alongside the evidence and the findings in the individual foot.

Anatomy and the column concept

The anatomical midfoot comprises the navicular, cuboid and three cuneiforms. The talus and calcaneus belong to the hindfoot, but they provide the proximal foundations for the functional columns of the foot. The metatarsal bases form the distal articulations of the midfoot. This distinction helps prevent confusion between an anatomical region and a reconstructive concept.

The Chopart complex is formed by the talonavicular and calcaneocuboid joints at the hindfoot-midfoot junction. The Lisfranc complex includes the tarsometatarsal articulations and their supporting ligamentous structures. Between these lie the naviculocuneiform and intercuneiform articulations. Precise naming matters: a talonavicular fusion, a naviculocuneiform fusion and a first-to-third tarsometatarsal fusion have different effects on movement and different mechanical demands.

I find a two-column model useful when planning reconstruction. In this model, the medial functional column includes the talar foundation, navicular, cuneiforms and first three rays. The lateral column includes the calcaneal foundation, cuboid and fourth and fifth rays. The model emphasises the relationship between a stable medial support and a lateral side that accommodates the ground.

The widely used three-column description subdivides the tarsometatarsal region into a medial first ray, a middle second and third ray complex, and a lateral fourth and fifth ray complex. The middle column therefore includes the intermediate and lateral cuneiforms with the second and third metatarsals, rather than the third ray alone. These descriptions serve different purposes; the chosen terminology must not obscure which joints are unstable, arthritic or intended for fusion. Preserving lateral-column mobility is particularly valuable where the fourth and fifth tarsometatarsal joints remain functional. [M1, M2]

Table 1 The two functional columns used in this chapter

Column	Proximal support and components	Reconstructive emphasis
Medial	Talus, navicular, three cuneiforms and rays 1-3	Restore alignment and stable support; define each joint to be fused.
Lateral	Calcaneus, cuboid and rays 4-5	Maintain length and preserve useful mobility where possible.

Alignment and the mechanics of loading

The hip, knee, ankle and foot form a connected kinetic chain. During examination, I consider the direction of the limb and its relationship to the second ray as a practical guide to functional progression. This clinical guide is distinct from the radiographic mechanical axis of the lower limb, which connects the hip and ankle centres. Foot alignment is three-dimensional and cannot be described adequately by extending a single line to a toe.

Assessment should include hindfoot position, arch height, talonavicular coverage, forefoot abduction or adduction and the relationship of the first ray to the ground. On radiographs, the talar and first-metatarsal axes are used to assess Meary alignment, whereas the second metatarsal provides a reference for the longitudinal axis of the metatarsus. These measures should be interpreted together with the loaded clinical appearance of the foot. [M3]

In a planovalgus or progressively collapsing foot, the arch may lower, the hindfoot may drift into valgus and the forefoot may abduct. Talonavicular uncoverage and failure of ligamentous support can increase the work required from the remaining soft tissues. Tibialis posterior dysfunction may contribute, but progressive collapsing foot deformity is not explained by one tendon alone. [M4]

A cavovarus foot may combine a high arch, hindfoot varus, a plantarflexed first ray and forefoot adduction. The deformity may originate predominantly in the forefoot, hindfoot or both. The Coleman block test helps assess whether hindfoot varus is flexible and driven by the forefoot. Muscle imbalance and neurological disease should be considered, particularly when deformity progresses or is asymmetric. [M5]

Both patterns can produce focal pressure and abnormal joint loading. Body mass, activity, footwear and the duration of loading influence the demands placed on the foot. However, neither a flat arch nor a high arch automatically establishes the cause of pain. An asymptomatic shape does not need reconstruction simply because it differs from an idealised drawing.

Tibialis posterior and tibialis anterior deserve careful assessment. Tibialis posterior supports inversion and arch control; tibialis anterior contributes to dorsiflexion and inversion and inserts into the medial cuneiform and first-metatarsal base. Their action must be considered alongside the peroneal tendons, Achilles-gastrocnemius complex, intrinsic muscles and plantar ligamentous structures. A technically satisfactory fusion can remain overloaded if a relevant deforming force is left untreated.

Progressive collapsing foot deformity

A collapsing foot is best understood as a three-dimensional change in support. Hindfoot valgus, forefoot abduction, medial-column instability and peritalar malalignment may coexist in different proportions. The newer term progressive collapsing foot deformity is useful because it avoids attributing the entire disorder to tibialis posterior alone. The tendon matters, but the spring ligament, deltoid complex, joint surfaces and geometry of the foot also determine the eventual shape. [M20]

The most important practical distinction is whether the deformity remains flexible. I examine the loaded foot and then correct the heel manually, observing what happens to the forefoot. The patient may show a flexible hindfoot but residual forefoot supination, or a rigid painful deformity with little useful movement. Heel-raise performance, calf tightness, skin pressure and the state of the ankle complete the mechanical picture. The label flatfoot is too broad to choose an operation.

An orthosis or ankle-foot brace can support the foot and reduce painful demand; physiotherapy works on the function that remains available. When symptoms justify reconstruction, a flexible foot may be treated with a tailored combination of osteotomy and soft-tissue procedures. Possible components include medial displacement of the calcaneus, correction of forefoot abduction, tendon transfer and selected ligament reconstruction. A rigid arthritic foot may require selective fusion. These are choices within a reconstruction, not procedures that every patient receives. [M4]

My emphasis on the medial column comes from its role in carrying load towards the forefoot. Once the heel is corrected, the first ray should participate in support without leaving the lateral forefoot to absorb a disproportionate share. An unstable or arthritic first tarsometatarsal or naviculocuneiform joint may need fusion; a preserved joint with a deformity that is suitable for osteotomy may not. The operative extent follows the location of disease and the correction required.

Where the ankle has tilted into valgus, the problem reaches beyond the foot. A foot reconstruction alone may leave an incompetent deltoid complex or an arthritic tibiotalar articulation untreated. The sequence and extent of surgery should therefore be planned across the ankle and hindfoot together, particularly where replacement or fusion is also being considered. This is a service-level decision in complex cases and benefits from shared review of the images and proposed correction.

Cavovarus and the high arched foot

A high arch may be a longstanding asymptomatic shape, a consequence of injury, or an expression of neuromuscular disease. Symptoms can include pressure beneath the metatarsal heads, lateral overload, recurrent ankle sprains, peroneal tendon pain and difficulty accommodating the foot in shoes. The question is not simply how high the arch appears, but why the foot has adopted that shape and where it has lost the ability to distribute load.

The Coleman block test helps distinguish a flexible hindfoot responding to a plantarflexed first ray from a more fixed heel deformity. Clinical examination also assesses motor balance, sensation, reflexes and progression. A progressive or asymmetric deformity requires consideration of neurological disease and appropriate further assessment. Orthoses may need to accommodate a rigid foot rather than force it towards an unattainable position. Reconstruction can combine tendon balancing, osteotomies and, where joints are rigid and arthritic, selective fusion. [M5]

The danger in surgical planning is to correct the appearance while leaving the deforming force active. An osteotomy changes bone alignment; a tendon procedure changes the direction or strength of a force; fusion removes motion from a painful or unstable articulation. They solve different parts of the same problem. I consider each proposed component in those terms before combining them.

The aim is a foot that meets the ground securely and can be accommodated in useful footwear. Complete radiographic normalisation may be unrealistic or unnecessary in longstanding deformity. Neuromuscular imbalance may continue to evolve, and the patient should understand how that affects recurrence and later treatment. The long-term plan includes footwear, strength and balance, monitoring of pressure areas and review when function changes.

Causes of midfoot pain and degeneration

Acute trauma may produce fractures, dislocations or predominantly ligamentous injuries. Lisfranc injury can follow either substantial trauma or a comparatively low-energy twisting event. Persistent pain after a seemingly modest injury warrants reassessment when the original diagnosis does not explain the disability. Post-traumatic arthritis may reflect the original cartilage damage, residual incongruity, instability or loss of column length. Chopart injuries similarly require attention to both joint congruity and the length of the foot columns. [M2, M6]

Degenerative disease may occur without a clearly remembered injury. Repetitive loading, established deformity and gradual instability can contribute to painful deterioration. In some patients, dorsal osteophytes interfere with shoes; in others, deep joint pain and impaired push-off dominate. Treating a prominent osteophyte alone will not correct an unstable or diffusely arthritic joint complex.

Systemic disease changes both diagnosis and treatment. Rheumatoid arthritis may cause synovitis, joint destruction and deformity. Systemic lupus erythematosus and systemic sclerosis may affect the assessment through inflammatory symptoms, soft-tissue changes, vascular disease, medication exposure or impaired healing. These

conditions should not all be labelled as direct equivalents of primary osteoarthritis. Rheumatology input is appropriate when disease activity or perioperative medication requires clarification.

Diabetes requires particular care. Neuropathy, impaired perfusion, infection and Charcot neuro-osteoarthropathy must be distinguished from ordinary degenerative arthritis. A hot, swollen foot in a person with neuropathy can represent active Charcot disease even when pain is modest or early radiographs are unrevealing. This requires prompt specialist assessment and protective offloading rather than entry into a routine arthritis injection or elective fusion pathway. [M7]

Bone quality is also important. Osteoporosis, nutritional deficiency and other metabolic problems may reduce fixation purchase or healing capacity. Bone health investigation should be directed by the history, risk profile and fracture pattern. The assessment includes smoking, harmful alcohol use, nutrition, diabetes control, vascular status and the patient's ability to follow the postoperative plan.

Clinical assessment and investigations

The consultation should establish where the patient feels pain, when it occurs and what has become difficult. Walking distance, standing tolerance, footwear, work and independence often provide more useful treatment goals than pain severity alone. Ask about previous injury, operations, inflammatory symptoms, neuropathy, ulceration and the response to previous treatment.

Examine the patient standing and walking where safe. Assess alignment from the front, side and behind, then examine the foot seated. Identify focal tenderness, swelling, instability, callosities and pressure points. Test tendon function, ankle motion, calf tightness and whether the deformity can be corrected passively. Record skin condition, protective sensation and circulation. The differential diagnosis includes stress injury, tendon pathology, neuropathic pain, infection and referred pain.

Weight-bearing dorsoplantar, lateral and oblique foot radiographs are central to chronic assessment. Hindfoot alignment views and ankle films may be needed where the deformity extends proximally. CT is useful for complex bony anatomy, joint involvement, deformity planning or uncertain union. MRI is reserved for a relevant question such as occult injury, tendon or ligament pathology, or a diagnostic uncertainty that plain films and CT do not resolve. [M1, M3]

In acute injury, loading should not be forced merely to obtain a standing radiograph. The clinical findings and available imaging determine whether CT, MRI, repeat imaging or specialist stress assessment is appropriate. Plantar bruising, marked midfoot swelling or inability to bear weight should heighten suspicion of significant injury. Open injury, threatened skin, vascular compromise or possible compartment syndrome requires urgent attention. [M2]

An image-guided local anaesthetic injection, sometimes combined with corticosteroid, may help assess a suspected pain-generating joint. The result should be interpreted cautiously because adjacent articulations may communicate and injectate can spread.

An injection supports clinical judgement; it does not substitute for a coherent diagnosis. [M1]

The painful accessory navicular

An accessory navicular is an additional ossicle or enlarged medial prominence near the insertion of tibialis posterior. Its presence on a radiograph does not establish that it is causing symptoms. Pain may arise from pressure within footwear, the interface between the ossicle and navicular, or adjacent tendon pathology. The assessment should localise tenderness and examine the tendon and overall foot alignment. Standing radiographs usually define the bony anatomy; MRI can help when tendon disease or diagnostic uncertainty remains. [M21]

The three common forms help describe the anatomy. Type I is a small ossicle within the distal posterior tibial tendon; type II has a synchondrosis connecting the accessory bone to the navicular; type III is a fused, prominent or cornuate tuberosity. Type II is particularly associated with a painful interface, but the type alone cannot establish the diagnosis. In my teaching, I emphasise focal tenderness, reproduction of the familiar pain, concordant imaging and the mechanical context before recommending surgery. [M22, M23]

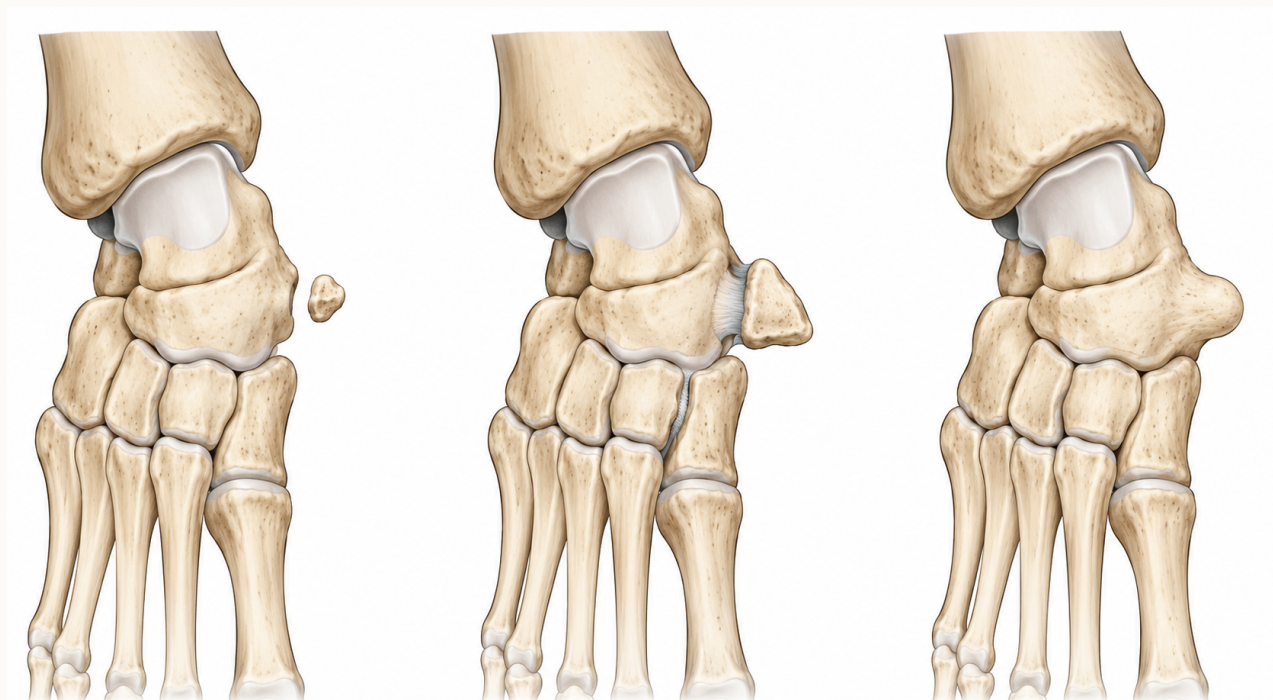


Figure 4.1 Accessory navicular morphology, from left to right: a separate small ossicle (type I), a larger ossicle adjoining the navicular through a synchondrosis (type II), and a prominent fused tuberosity (type III). Original conceptual artwork from the author's teaching presentation; tendon attachments and exact anatomical proportions are simplified.

Initial treatment usually combines activity modification, comfortable footwear, an orthosis that does not press directly on the prominence, and rehabilitation. A short period of immobilisation may help a particularly painful episode. Persistent local symptoms may justify excision with appropriate management or reattachment of the tibialis posterior insertion. Coexisting flatfoot deformity must be assessed separately

because isolated removal of the prominence may not correct the wider mechanical problem. [M21]

This condition illustrates an important discipline in foot surgery: a visible anatomical variation may attract attention before the actual source of disability has been established. I want the patient to understand whether the proposed operation addresses local shoe pressure, a painful interface, tendon dysfunction or a combination. The rehabilitation plan then follows the tissue that has been repaired, especially when the tendon insertion needs protection.

The operation should be the smallest reconstruction that addresses the demonstrated problem. Simple excision or naviculoplasty may suit a painful prominence when the tendon insertion remains competent. A modified Kidner procedure combines excision with the tendon repair, advancement or reattachment required by the individual anatomy. Selected larger type II ossicles can instead be considered for fusion to the navicular, preserving the insertion but introducing a requirement for bone union and a risk of nonunion. This is a selective option supported mainly by small clinical series, not a universally preferable treatment. [M22, M24]

My presentation on the painful accessory navicular describes the sequence as localising the pain, establishing whether the interface is active, controlling mechanics and then tailoring surgery. MRI oedema can support the diagnosis in an uncertain case, but it should not replace clinical correlation. Persistent pain following a technically satisfactory excision should prompt renewed assessment of tibialis posterior, planovalgus, hindfoot valgus, the medial column and scar or nerve symptoms. The visible ossicle may have been only one part of the original disorder. [M22]



Figure 4.2. Accessory navicular configurations and a conceptual illustration of marrow oedema around a symptomatic synchondrosis. The fourth panel is a diagram of an MRI finding, not a patient scan. Original educational artwork from Peyman Bakhshayesh, *The Painful Accessory Navicular*, 2026. PTT denotes posterior tibial tendon.

Chronic Lisfranc injury and post traumatic arthritis

A patient with chronic pain after a twisting injury may have travelled a long route before the midfoot becomes the focus of attention. The initial swelling may have subsided while deep pain, reduced push-off and widening or collapse gradually become more apparent. The history of apparently minor trauma should not be dismissed when the persistent disability is substantial. The aim is to establish whether the remaining problem is instability, established arthritis, deformity or an alternative diagnosis.

The second metatarsal base sits within the cuneiform arrangement, and the Lisfranc ligament complex helps preserve the relationship between the medial cuneiform and

second ray. Chronic disruption can therefore affect more than a single joint surface. Weight-bearing assessment, when safe, asks whether the rays remain aligned under load. CT clarifies established arthritic change and bony incongruity; MRI can answer selected ligament or occult-injury questions. The investigation is chosen to resolve a management decision rather than to collect every available image. [M2]

In an established painful arthritic complex, fusion may offer a dependable route to stability and pain relief. The reconstructive question is which joints must be included, how column length and arch position will be restored, and how lateral-column mobility can be retained where possible. The operation for a chronic malunited injury may be substantially more demanding than treatment of an acute injury because the soft tissues and bony relationships have adapted to the deformity.

The patient should understand that anatomical reduction cannot undo the original cartilage injury. The purpose of a salvage fusion is to create a stable and useful foot from the condition that exists now. A record of preoperative walking tolerance, work demands and footwear difficulty helps judge whether that purpose has been achieved. The acute recognition and management of Lisfranc injury are discussed in the trauma chapter; avoiding a missed unstable injury remains preferable to reconstructing its late consequences.

Nonoperative treatment

For chronic degenerative symptoms, treatment usually starts by reducing painful loading and improving the conditions in which the foot functions. A firm sole, rocker profile or appropriately selected full-length insert may reduce bending through painful joints. An orthosis should match the deformity and the patient's tolerance. Severe collapse may require a more supportive brace, while a rigid deformity may need accommodation rather than forceful correction.

Evidence for orthoses is encouraging but limited. A randomised feasibility study found signals of benefit from functional foot orthoses over a sham intervention, but its size and imprecise estimates do not establish a definitive effect for every patient. A practical trial should therefore be reviewed against pain, walking and footwear goals. [M8]

Rehabilitation aims to maintain useful movement, strengthen the available musculature and improve gait and balance. Calf stretching is appropriate when tightness contributes and the affected structures can tolerate it. Low-impact activity can help preserve fitness while painful loading is modified. Weight management should be discussed constructively as part of reducing demand and supporting general health, with goals that the patient can realistically sustain.

Analgesic and anti-inflammatory treatment should take account of comorbidity and other medicines. Image-guided corticosteroid injection may provide temporary relief and permit more effective rehabilitation. In a retrospective midfoot series, benefit was more evident early and declined with time. It should not be described as cartilage restoration or a durable correction of instability. Injection-related risks, including infection, local tissue effects and transient hyperglycaemia, belong in the individual discussion. [M9]

A stable acute injury may also be managed without surgery, but only after stability has been assessed and a protection and review plan established. Conversely, an unstable displaced injury does not need to exhaust the chronic arthritis pathway before operative treatment is considered. Timing and reconstruction depend on the injury, soft tissues and patient. [M2, M6]

Choosing the operation and its extent

For established arthritis, fusion is considered when pain and functional restriction remain unacceptable despite reasonable non-operative treatment and the symptomatic joints have been identified. The decision should include the consequences of stiffness, expected footwear needs, rehabilitation demands and the possibility of nonunion or further surgery.

The fusion must address the painful disease and the deformity responsible for abnormal loading. An isolated symptomatic joint, a first-to-third tarsometatarsal complex and an extended naviculocuneiform reconstruction are different operations. Healthy joints should be preserved when they do not need to be included for correction or stability. Lateral-column fusion requires particular justification because the fourth and fifth tarsometatarsal joints normally retain useful motion. [M2]

My two-column philosophy places emphasis on restoring dependable medial support. In selected severe collapse, revision or multilevel disease, an extended medial-column construct may be necessary. If a definitive fusion extends from the talus towards the first-metatarsal base, the talonavicular joint is included and its loss of motion must be justified explicitly. Talonavicular preservation is valuable when the joint is healthy and reconstructible. [M6]

My clinical alignment aim is a plantigrade foot, with the hindfoot around neutral to slight valgus, commonly within a 0-5 degree clinical target where appropriate. I seek a well-centred relationship of the talus beneath the tibia, satisfactory navicular coverage of the talar head and balanced progression towards the forefoot. This is an individual reconstructive goal, not a universal radiographic prescription. Medial-column correction alone may be insufficient if fixed hindfoot, ankle or proximal limb deformity remains.

Treatment logic across the midfoot

Dominant problem	Treatment principle	Important limit
Painful stable arthritis	Reduce bending through footwear or orthoses; selective fusion for persistent disabling symptoms	An image-guided injection supports localisation but spread may confuse the response
Flexible deformity with preserved joints	Correct alignment and rebalance the forces where appropriate	A tendon procedure alone may not correct the bony relationship
Rigid painful collapse	Select the arthritic or essential joints for corrective fusion	Fuse the joints required for the reconstruction; justify each additional joint
Chronic Lisfranc instability with arthritis	Restore alignment and obtain stable medial and middle-column support	Preserve useful lateral-column motion where possible
Revision nonunion or structural defect	Identify failure mechanism and restore mechanics, biology and length	A biological adjunct cannot compensate for infection or instability

Joint preparation and compression fixation

The operation begins with an exposure that allows accurate preparation while respecting the soft-tissue envelope. Skin bridges, cutaneous nerves, tendons and blood supply must be protected. The extent of exposure should be sufficient to achieve the reconstruction without unnecessary stripping.

My preference is to remove diseased cartilage and prepare opposing surfaces to viable bone while preserving the shape and length needed for correction. Controlled subchondral perforation or feathering can create a suitable fusion bed. Feathering describes deliberate preparation of the surface; it does not mean uncontrolled cracking, fragmentation or shortening of the column.

Reduction is obtained and checked before definitive fixation. Compression clamps help bring the prepared surfaces together. Compression must be applied in the intended direction without allowing malrotation or unwanted shortening. Residual gaps should prompt reassessment of preparation, reduction and the need for graft.

I favour compression combined with a plate construct that protects the correction against bending and torsion. Depending on the system, compression may come from an independent lag screw, the plate mechanism or a combination. A locking plate does not automatically compress the fusion surfaces merely because its screws lock into the plate. Implant design, screw distribution, bone purchase and the length of the reconstruction all matter.

In my Yorkshire practice, patients with higher body mass and greater loading demands influence how I plan fixation and postoperative protection. For an appropriate extended reconstruction, a robust anatomically suitable medial-column plate can be useful. Plate

selection remains specific to the patient's bone, soft tissues and correction. The objective of getting treatment right first time is sound planning and durable reconstruction; it is not an instruction to fuse more joints than necessary or to assume that a larger implant guarantees success.

A retrospective series of plantar midfoot constructs reported favourable union overall, but included mixed indications and greater difficulty in some higher-risk subgroups. Such evidence supports thoughtful construct selection; it does not establish universal superiority of one plate position, brand or loading schedule. [M10]

Primary fusion and the need for graft

In a straightforward primary fusion with good bone contact, preserved perfusion, satisfactory preparation and stable compression, I do not regard additional graft as automatically necessary. This is a case-specific decision. Being a non-smoker with no harmful alcohol use and good general health is favourable, but these factors alone cannot establish that graft is unnecessary.

Graft becomes more relevant when correction leaves a gap, bone stock is deficient, surfaces are sclerotic, a previous fusion has failed or substantial length must be restored. Local autograft may be sufficient for a modest defect. A larger defect requires an explicit plan for both biological incorporation and structural support. The roles of an osteoconductive scaffold, living autograft and a growth factor are different.

Revision surgery and the Diamond Concept

For revision and nonunion, I use the Diamond Concept associated with Professor Peter Giannoudis and colleagues as a framework for analysis. It brings together mechanical stability, osteogenic cells, an osteoconductive scaffold and osteoinductive signals. These elements function within a viable, vascularised environment and a patient whose general conditions support healing. The concept is a way to identify and address deficiencies, rather than a requirement to administer every available biological product. [M11]

Revision must begin by asking why the first reconstruction failed. Possible reasons include persistent deformity, inadequate compression, implant failure, poor bone contact, compromised biology or infection. Suspected infection requires appropriate investigation and tissue sampling, with staged treatment where indicated. Adding a graft product cannot compensate for unrecognised infection or an unstable construct.

In selected cases, my described marrow protocol uses approximately 60 mL of bone marrow aspirate obtained from the anterior iliac crest, near the anterior superior iliac spine, and processed to yield approximately 6 mL of concentrate. This is marrow aspirate rather than ordinary venous blood. The final volume and cellular content depend on the collection technique and processing system; the volume alone does not define biological potency. [M19]

BMAC supplies a mixed cellular preparation and is not a standardised dose of purified stem cells. Its role is adjunctive. A retrospective comparative midfoot study of a beta-tricalcium-phosphate scaffold combined with BMAC reported favourable union

findings, but the combination and study design do not establish the independent effect of BMAC or prove that every primary fusion benefits. [M12]

Recombinant human BMP-2 provides an osteoinductive signal and may be considered selectively in complex reconstruction. Midfoot arthrodesis falls outside the indications listed in the cited InductOs product information. Its use therefore requires an appropriate off-label rationale, local governance and informed consent, with current product information checked. Potential adverse effects include ectopic bone and inflammatory swelling; dose, carrier and placement cannot be generalised from another anatomical site. [M13]

A small retrospective subtalar and triple-fusion study reported poorer union with TutoBone than with autograft. That result cannot be extrapolated to every midfoot reconstruction, but it prevents these materials from being presented as established equivalents. Product choice should follow the defect, host and evidence rather than a fixed combination. [M15]

For larger defects, autologous graft may be harvested using the Reamer Irrigator Aspirator system, including from the femur when appropriate. It can provide a substantial graft volume, but donor-site planning must account for blood loss and the risks of cortical injury or fracture. The harvested material does not by itself replace the structural support needed for a length-restoring reconstruction. [M16]

The revision construct must restore alignment and protect the biological reconstruction. Compression is valuable where surfaces can be opposed; a structural defect may require a graft or other support that maintains length while healing develops. The final plate and screw configuration is chosen for the complete reconstruction, including the anticipated loading demands.

Table 2 Selected graft and scaffold options

Material	Nature and intended role	Practical qualification
Autologous bone graft	Patient-derived bone used to support incorporation and fill a defect.	Source, volume and structural requirements must match the defect; harvesting adds donor-site risk.
GreenBone b.Bone	Porous calcium-phosphate scaffold; manufacturer specifies 85% hydroxyapatite and 15% beta-tricalcium phosphate. [M14]	Distinct from hydroxyapatite/calcium-sulphate products. Check contraindications and current instructions; it does not replace required structural fixation.
TutoBone	Processed bovine cancellous xenograft providing an osteoconductive scaffold. [M15]	Neither synthetic bone nor living autograft. Discuss animal origin, alternatives and product-specific evidence.

Postoperative protection and rehabilitation

My usual pathway begins with a backslab while the wound and early swelling settle. The wound is reviewed at approximately two weeks. Where healing is satisfactory, I prefer transition to a protective boot. In selected patients with a stable construct, suitable bone and reliable adherence, I may allow protected weight-bearing in that boot from this stage.

This decision depends on more than wound closure. A healed skin incision does not establish fusion, and a strong plate remains vulnerable to fatigue if bone does not unite. The permitted loading, walking aids, boot use and review arrangements should be documented explicitly. Neuropathy, revision nonunion, major defects, tenuous fixation, poor bone, compromised perfusion or wound concerns may require a substantially longer period of protection.

Early-loading evidence must be matched to the operation. An 80-foot retrospective modified Lapidus series described successful protected loading from around two weeks, but that was a selected first-tarsometatarsal population. It cannot establish the safety of the same schedule for an extended talus-to-first-metatarsal reconstruction. The plantar midfoot series cited earlier introduced ordinary gait in a boot at six weeks. [M10, M17]

Rehabilitation starts with safe transfers, mobility planning and maintenance of strength in the rest of the limb. Later work addresses gait, balance, endurance and motion in joints that remain mobile. The fused joints should not be forced to move. Around three months, rehabilitation can become more progressive when the clinical and imaging findings support this. The three-to-four-month period is a useful anticipated healing milestone for an uncomplicated case, rather than a guarantee of complete union or full recovery. Swelling, conditioning and adaptation to footwear may take considerably longer.

Table 3 Review milestones in the author's selected-patient pathway

Stage	Assessment	Protection and progression
First 2 weeks	Wound, swelling, comfort, skin and safe mobility.	Backslab and elevation; loading only as prescribed.
Around 2 weeks	Wound healing, sensation, boot fit and construct suitability.	Transition to boot when appropriate. Protected loading only after an explicit clinical decision.
Around 6 weeks	Symptoms, standing alignment where permitted and radiographs.	Review fixation and developing union; maintain or adjust protection. An X-ray appointment alone is not clearance.
Around 3 months	Clinical progress and imaging evidence of union.	Progress gait, strengthening and footwear transition if sufficiently healed; investigate persistent focal pain.
Around 3-4 months and later	Confirm consolidation and functional recovery.	Healing may take longer, especially after revision. Continue tailored rehabilitation and review when needed.

Outcomes and the meaning of success

Successful surgery should improve the patient's life as well as the radiograph. Assessment includes pain, walking distance, stability, footwear, participation in work and confidence in daily activity. A primary arthritis series reported union in 92% of 104 feet, with improved pain and function, but also recorded further procedures and hardware removal. These results illustrate both the potential value of arthrodesis and the need for realistic expectations. [M18]

Complications include wound problems, infection, nerve symptoms, nonunion, malunion, hardware irritation or failure, transfer loading, adjacent-joint symptoms, persistent swelling and complex regional pain syndrome. Venous thromboembolism risk and prophylaxis should be assessed individually. Increasing pain, new deformity, wound discharge, progressive redness or boot-related pressure requires reassessment rather than automatic progression through the calendar.

The central principle of my approach is that alignment, fixation and biology must work together. A durable midfoot reconstruction begins with identifying the patient's actual problem, selects the joints that need treatment and restores a foot capable of carrying the patient's daily demands. Rehabilitation then translates the reconstruction into useful function. The intended result is dependable walking and improved independence, achieved with a clear understanding of both the strengths and the limits of the operation.

References for Chapter 4

[M1] British Orthopaedic Foot & Ankle Society. Midfoot arthritis. BOFAS Hyperbook. Accessed 14 October 2026.
[Read source](#)

- [M2]** AO Foundation. Treatment of Lisfranc injuries. AO Surgery Reference. Accessed 14 October 2026. [Read source](#)
- [M3]** British Orthopaedic Foot & Ankle Society. Part 2 Anatomical alignment. BOFAS Hyperbook. Accessed 14 October 2026. [Read source](#)
- [M4]** British Orthopaedic Foot & Ankle Society. Pes planus. BOFAS Hyperbook. Accessed 14 October 2026. [Read source](#)
- [M5]** British Orthopaedic Foot & Ankle Society. The cavovarus foot. BOFAS Hyperbook. Accessed 14 October 2026. [Read source](#)
- [M6]** AO Foundation. Treatment of Chopart injuries. AO Surgery Reference. Accessed 14 October 2026. [Read source](#)
- [M7]** National Institute for Health and Care Excellence. Diabetic foot problems prevention and management. NG19. Section 1.7 Charcot arthropathy. Accessed 14 October 2026. [Read source](#)
- [M8]** Halstead J, et al. Foot orthoses in the treatment of symptomatic midfoot osteoarthritis using clinical and biomechanical outcomes: a randomised feasibility study. *Clinical Rheumatology*. 2016;35:987-996. doi:10.1007/s10067-015-2946-6. [Read source](#)
- [M9]** Drakonaki EE, Kho JS, Sharp RJ, Ostlere SJ. Efficacy of ultrasound-guided steroid injections for pain management of midfoot joint degenerative disease. *Skeletal Radiology*. 2011;40:1001-1006. [Read source](#)
- [M10]** Fraser TW, Miles DT, Huang N, Davis FB, Dunlap BD, Doty JF. Radiographic outcomes, union rates, and complications associated with plantar implant positioning for midfoot arthrodesis. *Foot & Ankle Orthopaedics*. 2021;6(3). doi:10.1177/24730114211027115. [Read source](#)
- [M11]** Giannoudis PV, Einhorn TA, Marsh D. Fracture healing: the diamond concept. *Injury*. 2007;38 Suppl 4:S3-S6. doi:10.1016/S0020-1383(08)70003-2. [Read source](#)
- [M12]** Lee W, Prat D, Chao W, Farber DC, Wang C, Wapner KL. The efficiency of highly porous beta-tricalcium phosphate with bone marrow aspirate concentrate in midfoot joint arthrodesis. *Foot & Ankle Specialist*. 2026;19(2):123-132. First published online 2023. doi:10.1177/19386400231213177. [Read source](#)
- [M13]** European Medicines Agency. InductOs product information. Summary of product characteristics, sections 4.1, 4.3 and 4.4. Accessed 14 October 2026. [Read source](#)
- [M14]** GreenBone. b.Bone surgical technique. LT0001 EN Rev 01. Product composition, indications and precautions. Manufacturer document. Accessed 14 October 2026. [Read source](#)
- [M15]** Patil S, Auyeung J, Gower A. Outcome of subtalar fusion using bovine cancellous bone graft: a retrospective case series. *Journal of Foot and Ankle Surgery*. 2011;50(4):388-390. doi:10.1053/j.jfas.2011.04.019. [Read source](#)
- [M16]** Haubruck P, et al. Complications and risk management in the use of the reaming-irrigator-aspirator system: RIA is a safe and reliable method in harvesting autologous bone graft. *PLoS One*. 2018;13:e0196051. doi:10.1371/journal.pone.0196051. [Read source](#)
- [M17]** Blitz NM, Lee T, Williams K, Barkan H, DiDimenico LA. Early weight bearing after modified Lapidus arthrodesis: a multicenter review of 80 cases. *Journal of Foot and Ankle Surgery*. 2010;49(4):357-362. doi:10.1053/j.jfas.2010.04.014. [Read source](#)
- [M18]** Nemec SA, Habbu RA, Anderson JG, Bohay DR. Outcomes following midfoot arthrodesis for primary arthritis. *Foot & Ankle International*. 2011;32(4):355-361. doi:10.3113/FAI.2011.0355. [Read source](#)
- [M19]** Dragoo JL, Guzman RA. Evaluation of the consistency and composition of commercially available bone marrow aspirate concentrate systems. *Orthopaedic Journal of Sports Medicine*. 2020;8(1). doi:10.1177/2325967119893634. [Read source](#)
- [M20]** Myerson MS, Thordarson DB, Johnson JE, et al. Classification and nomenclature: progressive collapsing foot deformity. *Foot & Ankle International*. 2020;41:1271-1276. [Read source](#)
- [M21]** Parekh SG. The accessory navicular. American Academy of Orthopaedic Surgeons OrthoInfo Ortho-pinion. [Read source](#)
- [M22]** Bakhshayesh P. The Painful Accessory Navicular. Teaching presentation for the Round Table of Foot and Ankle Surgery, The Forefoot and Midfoot Revisited, York, 26 June 2026. Author source. [Read source](#)
- [M23]** Pediatric Orthopaedic Society of North America. Accessory navicular. POSNA Study Guide. [Read source](#)
- [M24]** Chung JW, Chu IT. Outcome of fusion of a painful accessory navicular to the primary navicular. *Foot & Ankle International*. 2009;30:106-109. [Read source](#)

CHAPTER 05

05 Forefoot conditions and balanced reconstruction

The philosophy of forefoot treatment

Forefoot conditions occupy a substantial part of elective foot and ankle practice. Hallux valgus, hallux rigidus, lesser-toe deformities, tailor's bunion and interdigital nerve pain can interfere with footwear, walking and work. A small area of pressure may become a major restriction in daily life. The patient's difficulty deserves the same careful assessment as disease affecting a larger joint.

My approach is to understand the deformity, identify the painful structure and consider how the whole foot is loaded. A prominent bunion, a raised second toe and pain beneath a metatarsal head may belong to the same mechanical problem. Treating each appearance separately can leave the underlying imbalance unresolved.



Figure 5.1 Clinical assessment begins with the patient's symptoms, footwear and functional needs. Original illustrative artwork; no real patient is depicted.

This chapter develops the assessment and treatment of common forefoot disorders, including my preferences for chevron, Scarf-Akin and selected Lapidus procedures. It explains the role of plantar-plate reconstruction, lesser-metatarsal osteotomy, interphalangeal fusion, cheilectomy and first metatarsophalangeal fusion. These operations have a common purpose: to reduce pain while restoring a foot that can be

used comfortably in daily life. Operative choices and rehabilitation remain specific to the patient and the reconstruction.

The scale of an operation does not tell us the scale of its consequences. A patient who cannot tolerate a work shoe may lose mobility and independence even when the radiographic abnormality appears modest. Equally, a conspicuous deformity may cause little difficulty. I therefore begin with the patient's account of walking, footwear and daily function. The appearance of the foot helps us understand the problem; it does not define the treatment goal on its own.

For me, balance in the forefoot means more than a straight great toe. It means preserving an effective first ray, respecting the plantar support of the lesser toes and distributing load across structures capable of accepting it. A correction that looks impressive on one view but leaves the first metatarsal elevated or shortened can exchange one area of pain for another. Every proposed correction must be considered in relation to its neighbours. [F1, F4, F7]

Assessment of the painful forefoot

The history should establish the precise site of pain, the activities that reproduce it and the shoes the patient can tolerate. Ask about duration, progression, previous surgery, injury, inflammatory symptoms and neurological disease. Burning into adjacent toes suggests a different mechanism from pain over a dorsal osteophyte or a plantar callosity. The patient should identify what improvement would make treatment worthwhile.

Examine the foot standing and walking when safe, then seated. Record hindfoot position, arch shape, first-ray alignment, calf tightness and pressure areas. Determine whether each deformity is flexible or fixed. Examine first metatarsophalangeal (MTP) movement, lesser-MTP stability, toe purchase and the intermetatarsal spaces. Assess protective sensation, circulation, skin integrity and any ulceration before planning elective correction. [F1, F4, F6, F7]

Table 5.1 Localising common sources of forefoot symptoms

Pattern	Assessment priority
Medial first-MTP prominence	Hallux valgus, footwear pressure, bursitis and joint condition
Dorsal first-MTP pain and stiffness	Dorsal impingement versus more extensive arthritis
Plantar pain beneath a lesser metatarsal	Loading, plantar plate, MTP stability and stress injury
Pain over a bent toe or at its tip	Flexible versus fixed deformity and pressure-related skin damage
Burning into adjacent toes	Interdigital nerve symptoms, bursitis and alternative causes
Lateral fifth-metatarsal prominence	Bunionette shape and lateral or plantar pressure

Weight-bearing dorsoplantar, oblique and lateral radiographs usually provide the starting point for structural deformity. They show alignment, joint space, metatarsal relationships and previous reconstruction. Ultrasound or MRI is useful when a focused question remains about a plantar plate, interdigital lesion or occult pathology. An imaging abnormality must correspond with the history and examination before it becomes a surgical target. [F1, F4, F7, F13]

A hot swollen joint, ulcer, spreading erythema, threatened skin or an acutely ischaemic toe needs a different pathway from routine elective deformity correction. Inflammatory arthritis, gout, infection, neuropathy and stress injury should remain in the differential diagnosis. New progressive clawing, especially with weakness or cavus deformity, warrants neurological assessment.

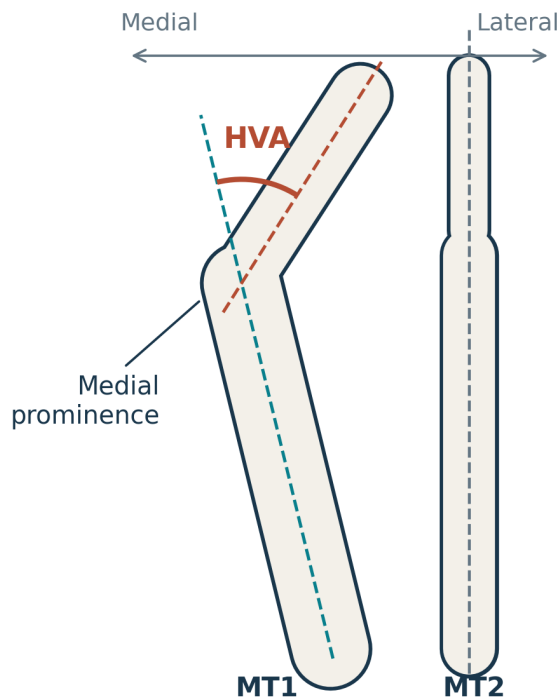
The patient's shoes are useful clinical evidence. Wear patterns, pressure marks and the width or stiffness of the sole may reveal why symptoms arise at work but improve in a different shoe. I also ask what the patient has already tried and whether it was practicable. An insole that cannot fit the only permitted work shoe, or a recovery plan that cannot be followed at home, is not a complete treatment plan.

Hallux valgus and first ray mechanics

Hallux valgus is a three-dimensional deformity. The first metatarsal deviates medially while the hallux deviates towards the second toe. The medial capsule becomes attenuated, lateral structures may contract and the tendon forces become increasingly deforming. The sesamoid complex becomes relatively lateral to the first-metatarsal head. The visible bunion therefore reflects altered alignment as well as local prominence. [F1]

Rotational deformity deserves particular attention. The first metatarsal is commonly pronated in hallux valgus. Weight-bearing CT research shows that the extent and

classification of abnormal pronation depend on the measurement and reference threshold used. Rotation, joint congruity and sesamoid position should be considered alongside the familiar planar angles. The hallux valgus angle is measured between the axes of the first metatarsal and proximal phalanx; the intermetatarsal angle describes the relation of the first and second metatarsals. These measurements describe components of the deformity rather than the whole patient. [F1, F2]



Hallux valgus angles

HVA

First metatarsal axis to proximal phalanx axis.

IMA

First to second metatarsal axes.



Axes translated to one origin for this angle schematic.

Dorsal-plane concept only. First-metatarsal pronation is a separate 3D component.

Figure 5.2 The hallux valgus angle (HVA) lies between the first-metatarsal and proximal-phalangeal axes. The intermetatarsal angle (IMA) lies between the first and second metatarsal axes. This planar schematic does not display coronal rotation.

The first tarsometatarsal (TMT) joint must also be assessed. Instability, medial-column dysfunction and a symptomatic flatfoot may influence the reconstruction. A low arch alone does not establish the need for Lapidus fusion, and correcting a bunion alone will not necessarily correct a separate hindfoot deformity. [F1, F3]

Treatment begins with accommodation: a sufficiently wide toe box, a comfortable upper, reduced heel height and appropriate pressure relief. Orthoses may help associated loading symptoms. These measures aim to improve comfort; they do not reliably reverse an established structural deformity. Surgery is considered for persistent pain and functional or footwear restriction after an appropriate trial of non-operative care.

Selecting hallux valgus correction

I favour a familiar, adaptable set of operations with which correction and fixation can be achieved predictably. A chevron osteotomy is useful for an appropriate lesser or selected moderate deformity, while Scarf-Akin can provide a wider range of correction when the joint surface and bone geometry permit. The hallux valgus and intermetatarsal angles inform this choice, but no isolated numerical cutoff determines the operation. Joint congruity, first-ray rotation, sesamoid position, metatarsal length, first-TMT stability, arthritis and the patient's symptoms must be considered together. [F1, F2, F3]

Table 5.2 Matching the operation to the problem

Procedure	Main purpose	Selection considerations
Chevron	Distal V-shaped metatarsal osteotomy with lateral head translation	Correctable mild or selected moderate deformity; preserve length and head blood supply
Scarf	Z-shaped first-metatarsal osteotomy	Larger correction where joint preservation and bone geometry permit
Akin adjunct	Medial closing-wedge proximal-phalangeal osteotomy	Residual phalangeal valgus; not a substitute for correcting metatarsal malalignment
Lapidus	Corrective first-TMT arthrodesis	First-ray instability, selected severe or recurrent deformity, or symptomatic TMT disease
First-MTP fusion	Corrective arthrodesis of the great-toe joint	Substantial symptomatic MTP arthritis or selected severe/revision deformity

The chevron and Scarf procedures require attention to metatarsal length, elevation, rotation and the relationship of the head to the sesamoids. Soft-tissue balancing is performed when needed. A lateral release should correct persistent tethering without sacrificing stability through excessive release. The Akin osteotomy refines the phalangeal component of correction. Screws, or a combination of screws and a staple, provide fixation according to the osteotomy and bone quality. [F1]

For appropriate first-TMT instability or deformity, I find Lapidus reconstruction useful. It corrects the first ray at its base and obtains stability through fusion. The preparation, correction and fixation must account for sagittal alignment and rotation as well as the IMA. Additional procedures depend on residual deformity. Lapidus is an arthrodesis and carries a different healing requirement from a distal osteotomy. [F3]

Many alternative open and minimally invasive osteotomies exist. The size of an incision is only one part of the decision; correction, soft-tissue preservation, reliable fixation and the surgeon's experience remain central. A painful arthritic first-MTP joint, severe metatarsus adductus, poor bone quality or revision surgery may alter the plan

substantially. A familiar operation should be used because it fits the problem, rather than because it is the operation most easily available. [F1, F3]

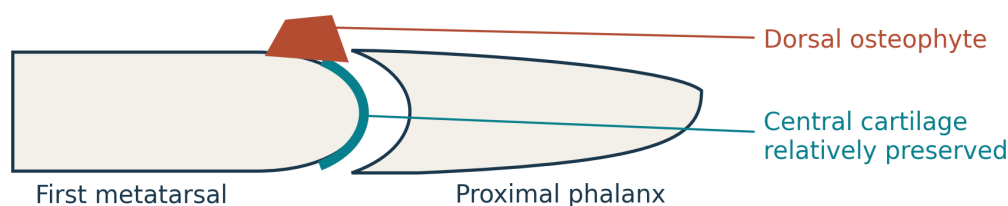
Hallux rigidus and joint preservation

Hallux rigidus is degenerative disease of the first MTP joint, involving the articulation rather than the metatarsal head alone. Patients describe stiffness, pain during push-off and difficulty with shoes that press on a dorsal prominence. Examination should distinguish pain from dorsal impingement at the end of dorsiflexion from pain through the middle of the remaining arc, which suggests more extensive articular disease. [F4]

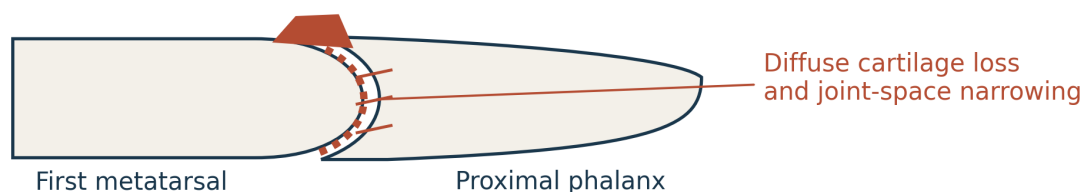
Initial measures include a roomy upper, a stiff sole or rocker profile, an appropriate footplate and modification of painful activities. Analgesia is individualised. A corticosteroid injection can offer temporary symptom relief in selected patients, but it does not restore the joint surface or remove a mechanical block. Treatment of coexisting gout or inflammatory disease is considered separately. [F4, F5]

Hallux rigidus: cartilage distribution matters

A. Dorsal impingement predominates



B. More extensive joint degeneration



Sagittal concept, dorsal = up. Cartilage status and symptoms guide treatment together.

Figure 5.3 Dorsal impingement with useful remaining joint surface differs from diffuse arthritis. Cheilectomy removes an impinging prominence; fusion addresses painful movement in an extensively diseased joint. Conceptual sagittal illustration, not an operative cutting guide.

Cheilectomy is valuable when dorsal osteophytes produce impingement and worthwhile joint function remains. It removes the impinging bone while preserving the articular surface and stability needed for movement. The phrase “edge arthritis” is a practical description of this presentation, not a formal disease stage. Cheilectomy should not be promised to resolve pain arising from diffuse cartilage loss. [F4, F5]

In my routine approach, a satisfactory wound review and suture removal at around two weeks may permit transition to a roomy shoe after isolated cheilectomy. Swelling can delay this. Gentle first-MTP movement is usually encouraged according to the wound and operative findings because maintaining useful motion is part of the purpose of the operation. The recovery of comfort is slower than closure of the skin.

First metatarsophalangeal fusion

Fusion is a dependable option for advanced symptomatic first-MTP arthritis when pain and restriction remain unacceptable. The patient must understand that the operation aims to relieve painful movement by permanently eliminating motion at that joint. The interphalangeal joint remains mobile unless separately diseased or fused. Footwear choice, kneeling and activities requiring substantial great-toe dorsiflexion should be discussed before surgery. [F4, F5]

My preference is thorough removal of diseased cartilage, preparation of viable opposing bone and compression in an appropriate functional position. Controlled perforation or feathering of subchondral bone may be used. This means deliberate surface preparation, not uncontrolled fracturing or excessive shortening. The selected position should allow comfortable toe clearance and contact in the patient's anticipated footwear.

Compression screws, a plate and screw construct, or another suitable fixation system may be used. Fixation must resist the forces acting across the fusion while biological union develops. A construct that feels solid at surgery is not yet a healed fusion. Bone quality, deformity, smoking, diabetes, revision status and the patient's ability to protect the foot influence the postoperative prescription.

For selected patients with satisfactory fixation, my approach allows protected weight-bearing through the heel in a prescribed postoperative shoe. A wound review is arranged at approximately two weeks. At around six weeks, clinical and radiographic findings help determine whether loading and footwear can progress. A return to ordinary shoes at six weeks is a possibility in selected cases, not a guarantee; some established protocols require substantially longer protection. [F5]

Choosing between preservation and fusion

The choice is made from the patient's symptoms, the condition of the joint and the value of the remaining movement. A relatively mobile joint with predominantly dorsal impingement may justify cheilectomy. A joint with severe pain throughout movement, marked narrowing and little useful function is more likely to benefit from fusion. Imaging severity alone should not replace the clinical discussion.

Selected patients may be offered other joint-preserving osteotomies or arthroplasty procedures. Their indications, durability and revision implications require separate discussion. My emphasis in this chapter is on cheilectomy and fusion because these are the operations described in my clinical approach. Failure of cheilectomy may lead to later fusion; failure of fusion requires investigation of union, position, infection and adjacent sources of pain.

The discussion should make the trade-off tangible. Joint preservation retains movement but may leave residual arthritis and the possibility of further surgery. Fusion exchanges painful movement for stability and requires bony union in a useful position. Patients often find this easier to understand when it is related to their usual shoes, stairs, kneeling and recreational activities. The best choice is the one that addresses the dominant pain mechanism and fits the patient's priorities. [F4, F5]

Lesser toe deformities and plantar plate failure

The lesser toes work with the plantar plates, collateral ligaments, long tendons and intrinsic muscles to maintain ground contact and resist excessive MTP extension. Plantar-plate attenuation or rupture can lead to instability, typically at a lesser MTP joint and often the second. It is an important cause of painful progressive deformity, but it is not the initiating event in every hammer toe. [F6, F7]

As MTP extension and subluxation develop, the balance of tendon forces changes. The long extensors act strongly at the MTP joint, while flexor and intrinsic imbalance contributes to interphalangeal flexion. Progressive displacement of the plantar plate and changes in tendon leverage reduce effective MTP stabilisation and toe purchase. A flexible deformity may become fixed as the capsule and soft tissues contract.

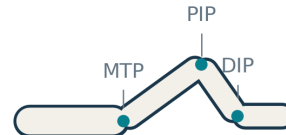
Lesser-toe patterns in the sagittal plane

Normal



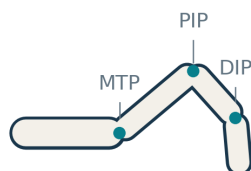
Neutral alignment

Hammer toe



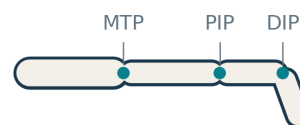
PIP flexion; MTP may extend

Claw toe



MTP extension; PIP + DIP flexion

Mallet toe



Isolated DIP flexion

Dorsal = up • Plantar = down • Metatarsal at left; toe tip at right

MTP: metatarsophalangeal PIP: proximal interphalangeal DIP: distal interphalangeal

Figure 5.4 Lesser-toe deformities are defined by the joints involved. Hammer toe primarily involves PIP flexion; claw toe combines MTP extension with PIP and DIP flexion; mallet toe primarily involves DIP flexion. MTP posture in hammer toe is variable.

Patients commonly report a painful corn or callosity over the proximal interphalangeal (PIP) joint, pressure at the toe tip or pain beneath a metatarsal head. The dorsal lesion

is usually pressure-related keratosis rather than a primary scar. Advanced instability may produce loss of toe purchase, spreading or crossover of the toe. Skin breakdown is particularly consequential when sensation or perfusion is impaired.

Examination includes passive correction of each joint and an MTP drawer test, interpreted alongside plantar tenderness and toe purchase. Assess hallux valgus, metatarsal length and loading, calf tightness and neurological or inflammatory disease. Ultrasound or MRI may clarify a suspected plantar-plate lesion when the result will influence management. [F7]

Reconstructing the lesser toes

A deep, spacious toe box, soft padding, suitable insoles and pressure redistribution are reasonable first measures. Selected flexible deformities may benefit from taping or splinting. A metatarsal pad is positioned to redistribute load proximal to the painful heads rather than simply increasing pressure directly beneath them. Persistent pain, recurrent pressure damage or progressive instability may justify surgery.

The operation must address the relevant levels of deformity. Correction of a rigid PIP joint will not automatically stabilise a deficient plantar plate. Conversely, an MTP reconstruction will not straighten a fixed PIP contracture. The first ray and neighbouring metatarsals should be considered where they contribute to overload.

Plantar plate repair and metatarsal shortening

When a repairable plantar-plate tear contributes to instability, direct repair or reconstruction may be appropriate. Dedicated instruments can assist suture passage through selected approaches. Their availability does not determine the indication or demonstrate superiority over other methods. Published clinical series support repair in selected cases, while the pattern of deformity, tissue quality and associated loading remain essential to selection. [F8, F10]

A relatively long or overloaded metatarsal may require controlled shortening to help reduce the joint and relieve tension. The commonly used Weil osteotomy is an oblique distal-metatarsal osteotomy, with translation and screw fixation. Shortening must preserve an appropriate metatarsal relationship. Excessive shortening, altered head position, stiffness and a floating toe are recognised concerns. The objective is a supported toe and comfortable load distribution, not shortening for its own sake. [F9]

In selected contracted deformities, a McGlamry elevator can help release adhesions beneath the metatarsal head and mobilise the joint. This is a release, not a plantar-plate repair. Further disruption of useful plantar restraints should be avoided. Patient age alone is insufficient reason to choose release and pinning over reconstruction; tissue quality, reducibility, symptoms and functional demand are more useful determinants.

Correction of the interphalangeal joints

For a fixed painful hammer toe, PIP arthrodesis may be achieved by preparing the opposing joint surfaces and maintaining alignment with a K-wire or an appropriate internal device. Selected patients may instead undergo resection arthroplasty. Tendon lengthening, transfer or other balancing procedures are added according to the flexible component of deformity. The final correction should preserve a useful toe position and avoid excessive shortening.

Temporary K-wire fixation may hold the correction while soft tissues and bone heal. In my usual hammer-toe pathway the wire is reviewed for removal at approximately six weeks. Removal depends on the procedure, stability, skin and pin site. Patients must protect an exposed wire, keep the prescribed dressing dry and seek advice if it loosens, migrates or becomes painful or inflamed. [F15]

Tailor bunion and curly toe

Lateral-border pressure and smaller-toe deformity deserve the same diagnostic discipline as first-ray disease. The visible prominence or underlapping toe should be related to its pressure lesion, flexibility and effect on footwear before an operation is selected.

Tailor bunion

A tailor's bunion, or bunionette, is a symptomatic prominence around the fifth-metatarsal head. Pressure from footwear may cause lateral bursitis, callosity or plantar-lateral pain. The deformity may reflect an enlarged head, lateral bowing of the fifth metatarsal, an increased fourth-to-fifth IMA or a combination. The location of the pressure lesion helps explain the patient's symptoms. [F11]

Initial treatment uses a wider shoe, a soft upper, padding and appropriate offloading. Standing radiographs help define the bony component when surgery is contemplated. Persistent symptoms may be addressed by a selected fifth-metatarsal osteotomy, with or without limited prominence resection. An isolated exostectomy is less suitable when malalignment is the main driver. Correction should preserve useful fifth-ray support and avoid creating a new plantar pressure point. [F11]

Curly toe

Curly toe usually combines flexion with rotation and an underlapping position. Flexor tightness is an important contributor. Congenital curly toes in children must be distinguished from acquired adult deformity: an asymptomatic childhood toe often needs observation, whereas persistent symptoms and pressure problems may justify treatment. Paediatric surgical guidance should not simply be transferred to adult forefoot reconstruction. [F12]

In symptomatic adult practice, treatment depends on flexibility and the joints involved. A flexible deformity may respond to selective flexor tenotomy or lengthening; a more complex toe may need additional soft-tissue balancing or joint correction. Routine division of both flexor and extensor tendons is not a universal solution. The procedure

should release the structures responsible for the deformity while retaining useful function.

Temporary wire fixation is used only where the correction requires it. My review window for selected soft-tissue toe procedures is approximately three to six weeks, with removal determined by stability and healing. This should not be interpreted as evidence that every toe reconstruction has healed fully by three or four weeks.

Metatarsalgia and associated disease

Metatarsalgia describes pain around the metatarsal heads; it is not a final diagnosis. First-ray dysfunction, lesser-MTP instability, metatarsal overload, inflammatory synovitis, stress injury, Freiberg disease and interdigital nerve symptoms can produce overlapping complaints. Treatment should follow the cause. In rheumatoid disease, medical control and the state of the joints may alter both the timing and extent of reconstruction. A shortening osteotomy is not a general treatment for unexplained forefoot pain.

Morton neuroma

Morton's neuroma is a painful interdigital nerve disorder associated with fibrotic change, most often in the third intermetatarsal space between the third and fourth toes. Despite its name, the usual lesion is not a true nerve tumour. Patients may describe burning, electric pain, tingling or the sensation of a small stone beneath the forefoot, often aggravated by constricting shoes. [F13]

Examination includes webspace tenderness and reproduction of the familiar symptoms by forefoot compression. A Mulder click or clunk can support the diagnosis but is neither required nor sufficient on its own. Plantar-plate disease, intermetatarsal bursitis, MTP synovitis and neuropathy should be considered. Ultrasound or MRI can assist when uncertainty remains, but an incidental imaging lesion without corresponding symptoms should not become an indication for excision. [F13]

Treatment begins with a broad toe box, lower heels and reduction of aggravating pressure. A suitable metatarsal dome or bar may help. A carefully placed local anaesthetic and corticosteroid injection can provide symptom relief and may support localisation. A randomised trial found improved patient-rated foot health at three months with corticosteroid plus local anaesthetic compared with anaesthetic alone; this does not guarantee durable resolution for every patient. Injection counselling includes local fat-pad or skin effects as well as infection. [F14]

If disabling, well-localised symptoms persist, operative treatment may be considered. Options include selected decompression procedures or neurectomy. In my described approach, excision of the symptomatic nerve segment is an option when conservative treatment has failed. The operation intentionally interrupts sensation in the supplied interdigital area, and persistent numbness should be explained before consent.

The discussion also includes residual pain, painful scarring, stump neuroma and the possibility that another forefoot disorder contributes to symptoms. A technically successful excision cannot resolve pain from an unrecognised unstable MTP joint. Early

postoperative loading and shoe progression depend on the approach, wound and any combined procedure.

Combining procedures

A patient may need treatment at more than one site, but each addition requires a clear indication. Combined bunion and lesser-toe correction can address related mechanics; it also increases swelling and rehabilitation demands. If a plantar-plate repair, fusion or osteotomy requires greater protection than the accompanying procedure, the more restrictive requirement determines the initial recovery plan.

Staging may be appropriate when the main source of symptoms is uncertain, when the soft tissues would be excessively challenged by a large combined reconstruction, or when the practical demands of recovery are substantial. A staged plan is a positive decision about the sequence of care. It gives the patient a clear first objective and permits reassessment before further intervention, rather than accumulating procedures simply because several abnormalities appear on the radiograph.

Postoperative protection and rehabilitation

Secure fixation allows selected patients to mobilise early, but the loading instruction must be explicit. For these selected forefoot procedures, I prescribe limited weightbearing through the heel in the specified postoperative shoe, avoiding forefoot push-off; the allowed activities, aids and review date are recorded. It does not mean unrestricted walking, barefoot loading or immediate return to normal footwear. The patient should demonstrate safe use of the prescribed shoe and any walking aid.

Table 5.3 Practical review points for the author's described pathways

Procedure	Initial protection	Progression and review
Chevron or Scarf-Akin	Selected cases: heel-only loading in prescribed offloading shoe; protective dressing	Wound and sutures about 2 weeks; clinical and radiographic review about 6 weeks before gradual forefoot loading
Lapidus fusion	Separate fusion protocol; source leaflet uses non-weight-bearing for 6-8 weeks	Progress according to construct, union and clinical review; do not copy the distal-osteotomy schedule
PIP fusion or lesser-toe reconstruction	Heel protection and wire care; respect any plantar-plate repair	Wound review about 2 weeks; K-wire review/removal commonly around 6 weeks
Isolated cheilectomy	Postoperative shoe; wound protection and prescribed gentle MTP movement	Roomy shoe may be possible after about 2 weeks if healed and comfortable
First-MTP fusion	Selected cases: heel-only loading in a prescribed rigid postoperative shoe	Wound review about 2 weeks; assess healing around 6 weeks; footwear may need longer
Selected curly-toe soft-tissue surgery	Protect correction; temporary wire only if needed	Review wire removal in a 3-6 week window; timing depends on the actual procedure

These are review points, not guaranteed recovery dates. My Scarf-Akin rehabilitation document continues heel protection to six weeks and starts first-MTP mobilisation after the healing review. Other protocols begin movement earlier. A combined repair may require additional restrictions, so one written plan should identify which movement and loading are permitted. [FA1, FA2, F5, F15]

Swelling control, elevation, dressing care and appropriate analgesia support recovery. Thromboembolic risk and the need for prophylaxis are assessed individually under the local pathway. Rehabilitation then progresses towards comfortable footwear, gait, strength and balance. A patient with an MTP fusion should not be instructed to mobilise the fused joint.

Outcomes complications and clinical judgement

Forefoot surgery is judged by relief of pain, improved footwear tolerance and useful walking. Radiographic correction is important, but it does not replace the patient's experience. Persistent swelling, stiffness and altered sensation can outlast the initial wound and bone-healing period. Work, driving and sport require individual assessment of comfort, safe function and the restrictions associated with the procedure.

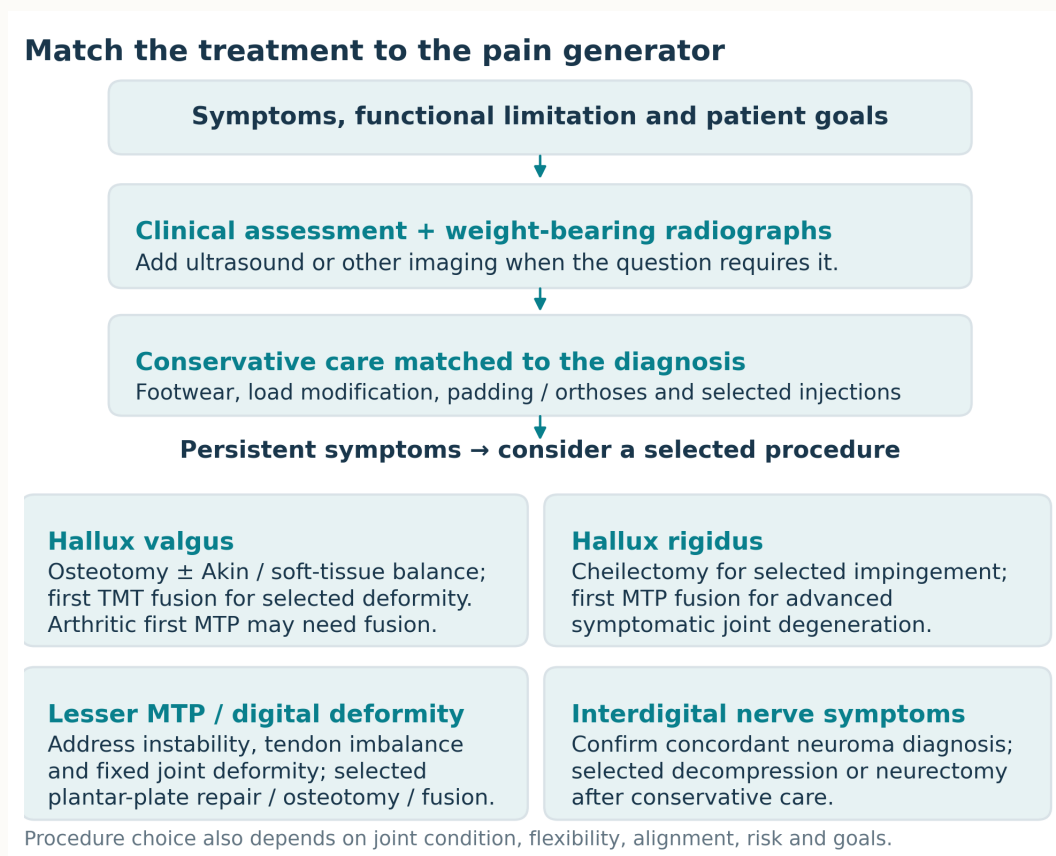


Figure 5.5 Treatment follows the symptomatic structure and the patient's response to appropriate non-operative care. The diagram summarises principles; mixed deformities and combined procedures require an integrated plan.

Persistent pain after apparently satisfactory correction deserves a new diagnostic assessment. Examine the distribution of tenderness, first-ray loading, lesser-MTP stability, wound and nerve symptoms, and the condition of adjacent joints. Radiographs may help assess union and position; further imaging is directed by the unresolved question. Revision surgery should address an identified mechanism, such as nonunion or symptomatic malalignment, and should not be undertaken merely because the first operation did not meet expectations.

Consent should cover infection, wound problems, nerve injury, stiffness, persistent pain, complex regional pain syndrome and further surgery where relevant. Osteotomies and fusions additionally require discussion of delayed union, nonunion, malunion and symptomatic implants. Hallux valgus can recur or be overcorrected into hallux varus. Lesser-toe surgery can leave a floating, recurrently deformed or stiff toe. These risks should be related to the actual reconstruction rather than presented as one generic percentage. [F1, F3, F4, F5, F6, F7, F8, F9, F15]

Increasing pain, spreading redness, drainage, fever, pin-site concerns or a pale, blue, cold or newly numb toe require prompt assessment. New calf swelling, chest pain or breathlessness requires urgent evaluation for thromboembolism. Follow-up should continue when there is uncertain healing, ongoing pain, wound difficulty or failure to regain function; six weeks is not an automatic discharge date.

The principle guiding my forefoot practice is to correct the source of the patient's difficulty while preserving useful function. Assessment defines what must be corrected,

fixation protects that correction and rehabilitation allows the patient to use it. A comfortable, balanced foot that meets the patient's daily needs is the intended result.

References for Chapter 5

- [F1]** British Orthopaedic Foot & Ankle Society. Hallux valgus. BOFAS Hyperbook. [Read source](#)
- [F2]** Lalevée M, et al. Distribution, prevalence, and impact on the metatarsosesamoid complex of first metatarsal pronation in hallux valgus. *Foot and Ankle Surgery*. 2023;29(6):488-496. doi:10.1016/j.fas.2023.06.003. [Read source](#)
- [F3]** American Orthopaedic Foot & Ankle Society. Lapidus procedure. FootCareMD. [Read source](#)
- [F4]** British Orthopaedic Foot & Ankle Society. Hallux rigidus. BOFAS Hyperbook. [Read source](#)
- [F5]** Royal National Orthopaedic Hospital. A patient's guide to arthritis of the big toe with discussions on cheilectomy and fusion. January 2026. [Read source](#)
- [F6]** British Orthopaedic Foot & Ankle Society. Lesser toe deformities. BOFAS Hyperbook. [Read source](#)
- [F7]** British Orthopaedic Foot & Ankle Society. Lesser MTP joint instability and plantar plate disorders. BOFAS Hyperbook. [Read source](#)
- [F8]** Nery C, Coughlin MJ, Baumfeld D, Mann TS. Lesser Metatarsophalangeal Joint Instability: Prospective Evaluation and Repair of Plantar Plate and Capsular Insufficiency. *Foot and Ankle International*. 2012;33(4):301-311. doi:10.3113/FAI.2012.0301. [Read source](#)
- [F9]** Trnka HJ, et al. The Weil osteotomy for treatment of dislocated lesser metatarsophalangeal joints. *Acta Orthopaedica Scandinavica*. 2002;73:190-194. [Read source](#)
- [F10]** Arthrex. Plantar plate repair. Manufacturer information describing repair instruments and technique; not comparative clinical evidence. [Read source](#)
- [F11]** British Orthopaedic Foot & Ankle Society. Bunionette deformity. BOFAS Hyperbook. [Read source](#)
- [F12]** Pediatric Orthopaedic Society of North America. Curly toe. Physician study guide. [Read source](#)
- [F13]** British Orthopaedic Foot & Ankle Society. Morton's neuroma. BOFAS Hyperbook. [Read source](#)
- [F14]** Thomson CE, et al. Methylprednisolone injections for the treatment of Morton neuroma: a patient-blinded randomized trial. *Journal of Bone and Joint Surgery American*. 2013;95(9):790-798. doi:10.2106/JBJS.I.01780. [Read source](#)
- [F15]** Royal National Orthopaedic Hospital. A patient's guide to bunion and lesser toe deformities. January 2026. [Read source](#)
- [FA1]** Bakhshayesh P. Rehabilitation pathway described in the supplied Chapter 5 Forefoot Conditions. Author manuscript, 14 October 2026. The underlying practice leaflet is referenced in that manuscript.
- [FA2]** Bakhshayesh P. Rehabilitation pathway described in the supplied Chapter 5 Forefoot Conditions. Author manuscript, 14 October 2026. The underlying practice leaflet is referenced in that manuscript.

CHAPTER 06

06 Biomechanics of the Foot

Understanding the foot through function

Understanding biomechanics is central to my approach to foot and ankle surgery. A patient presents with pain, difficulty walking, an altered shape or an inability to wear ordinary shoes. The surgeon's responsibility is to connect these experiences to the way the limb accepts load and produces movement. The radiograph contributes to that explanation, but the patient walking across the room often provides the first important information.

I examine the foot within the whole person. Body weight, activity, footwear, muscle strength, sensation, the shape of the limb and the condition of the knee and hip all deserve attention. A local deformity may initiate abnormal loading, compensate for a problem elsewhere, or represent both processes. Treatment becomes more rational when these relationships are understood. This whole-limb perspective also underpins the clinical approach described on my Leeds Ankle and Foot Surgery website. [B29]

The foot must adapt sufficiently to the ground while transmitting force effectively during progression. Its behaviour changes throughout each step. Bone geometry, articular motion, ligaments, plantar fascia and muscle activity work together; none provides a complete explanation in isolation. Research on the windlass, intrinsic muscles and midtarsal motion has made this interaction clearer. [B1, B2, B3, B4, B5, B6, B7, B8]

This chapter explains normal gait, the longitudinal and transverse arches, muscle balance, planovalgus and cavovarus deformity, clinical assessment and the interpretation of weight-bearing images. It illustrates Meary's angle, calcaneal pitch, Böhler's angle and the angle of Gissane, together with forefoot abduction and adduction. The purpose is to turn measurements into clinical reasoning: what is painful, what is deforming, what remains flexible and what treatment can realistically change.

The organising principle

A successful reconstruction should serve the patient's walking and daily life. Alignment, stability, retained movement and the capacity of the soft tissues to tolerate load must be considered together. A foot can look different from a textbook illustration and function well; a technically corrected angle can coexist with pain and poor function.

Functional architecture and mechanical language

The ankle and foot form a series of interacting segments. The tibiotalar joint provides most ankle dorsiflexion and plantarflexion. It behaves broadly as a hinge, but its oblique, changing axis and coupled rotations make it more complex than a simple door hinge. The hindfoot comprises the talus and calcaneus; the subtalar articulation helps the foot accommodate the ground and couples hindfoot motion with rotation of the leg.

The transverse tarsal or Chopart complex comprises the talonavicular and calcaneocuboid joints. More distally, the naviculocuneiform and tarsometatarsal joints contribute to arch shape and segmental adaptation. The relatively constrained central rays and more mobile lateral column have different roles. The first ray, first metatarsophalangeal joint and sesamoid complex influence medial forefoot loading and the final part of stance.

Three planes must be described separately

Sagittal-plane observations include arch height, ankle dorsiflexion and first-ray plantarflexion. Coronal-plane observations include heel varus or valgus and the relationship of the forefoot to the hindfoot. Transverse-plane observations include forefoot adduction or abduction and rotation of the whole foot relative to the direction of travel. Pronation and supination describe coupled three-dimensional movement, not simply a low or high arch.

In open-chain language, pronation combines eversion, abduction and dorsiflexion; supination combines inversion, adduction and plantarflexion. During weight-bearing, which bone moves relative to which reference segment matters. A description should therefore name the segment, the plane and the loading condition. “The heel is valgus during standing” is more informative than “the foot is pronated”.

Load, pressure and moment

Force is a push or pull. Plantar pressure describes force distributed over contact area, so the same load concentrated beneath a small prominence can become poorly tolerated. A joint moment depends on force and its perpendicular distance from the joint axis: $M = F \times d$. Altering heel position, shoe geometry or the ground-reaction-force path can change this moment without changing body weight.

Stiffness is resistance to deformation, expressed conceptually as a change in force divided by a change in displacement. It is different from rigidity. A foot may become functionally stiffer during propulsion while its joints continue to move. [B3, B5, B6]

The medial and lateral longitudinal arches share load with the transverse architecture. Experimental work demonstrates that transverse curvature and connecting tissues contribute substantially to longitudinal foot stiffness. It is therefore incomplete to understand the foot only from a lateral silhouette. These findings establish a mechanical principle; they do not provide a stand-alone surgical correction target. [B8]

Gait analysis and the progression of load

A gait cycle runs from one foot's initial contact to its next initial contact. At a comfortable walking speed, stance commonly occupies approximately 60% of the cycle and swing approximately 40%; speed, impairment and walking aids alter these proportions. [B26] The following phases provide a framework for observation, rather than a demand that every patient follow identical timings.

Phase	Mechanical task	Clinical observation
Initial contact and loading response	Accept load and lower the forefoot under control	Heel contact, foot slap, abrupt pain avoidance, knee stability
Midstance	Progress the tibia over the supporting foot	Arch deformation, ankle dorsiflexion, heel alignment, pelvic control
Terminal stance	Advance over the forefoot as the heel rises	Heel-rise timing, resupination, first-ray support and hallux movement
Preswing	Unload the trailing foot and initiate limb advancement	Propulsive contribution, toe loading and transfer to the opposite limb
Swing	Clear the ground and position the limb for contact	Foot drop, toe clearance, circumduction, step length and symmetry

The heel rocker, ankle rocker and forefoot rocker describe progression around successive supporting regions. Loss of movement at one level can shift demand elsewhere. For example, limited tibiotalar dorsiflexion may be accompanied by early heel rise, outward foot progression or apparent movement through the midfoot. A painful first metatarsophalangeal joint may lead the patient to shorten the opposite step or roll over the lateral border.

The plantar centre of pressure is the location of the resultant plantar force at an instant. It usually progresses from the rearfoot towards the forefoot, with a pattern influenced by speed, footwear and individual anatomy. It is not an anatomical line that must pass through the second toe in every person. Nor is a visually straight limb proof of normal internal joint loading.

I first watch the patient walking at a natural pace, with their usual aid when needed. I then compare barefoot and shod walking where safe. Front, rear and side views reveal different information. Note walking speed, step width, asymmetry, trunk lean, foot progression and the phase at which pain alters the step. Repeated observation often separates a consistent finding from a hesitant first attempt.

Video, plantar-pressure measurement, force plates, electromyography and three-dimensional gait analysis can answer more focused questions. Kinematics describes movement; kinetics describes forces and moments. Skin-marker models are useful but cannot perfectly represent every small tarsal joint. Instrumented analysis should resolve a clinical uncertainty and be interpreted alongside examination.

Clinical gait analysis should be reproducible enough to guide a decision. I record the walking condition as well as the finding: shoes or barefoot, usual walking aid, comfortable or faster pace, and the distance over which the symptom appears. A patient who walks well for ten metres may develop lateral pain after several minutes, while someone anxious in the clinic may appear more disabled than they are in familiar surroundings. When the main complaint is endurance, the assessment should include an appropriately safe task that approaches the patient's real difficulty.

The point of observation is to connect an alteration to a possible explanation. Early heel rise can accompany restricted dorsiflexion, but it may also be an avoidance strategy for pain. A short stance phase identifies reluctance to load the limb without identifying the damaged tissue. Foot slap suggests inadequate control during loading, yet its cause still requires examination. Each observation generates a question; palpation, movement testing, neurological assessment and imaging then refine the answer.

The mechanical axis of the hip, knee and ankle is useful for understanding the limb as a chain. Extending this concept towards the second ray can be a helpful clinical image, but it is not a universal geometrical rule for the path of force during gait. The ground reaction force changes position and direction, and muscles contribute substantial internal joint forces. A patient should not undergo an operation simply because a line drawn on a standing photograph fails to pass through a chosen toe.

The windlass mechanism

The plantar aponeurosis extends from the plantar calcaneus towards the toes through its distal slips. In the classical windlass model, dorsiflexion at the metatarsophalangeal joints winds this tissue around the metatarsal heads. The resulting tension tends to draw the heel and forefoot towards one another and elevate the longitudinal arch. The metatarsal head acts as a pulley within this simplified mechanism. [B1]

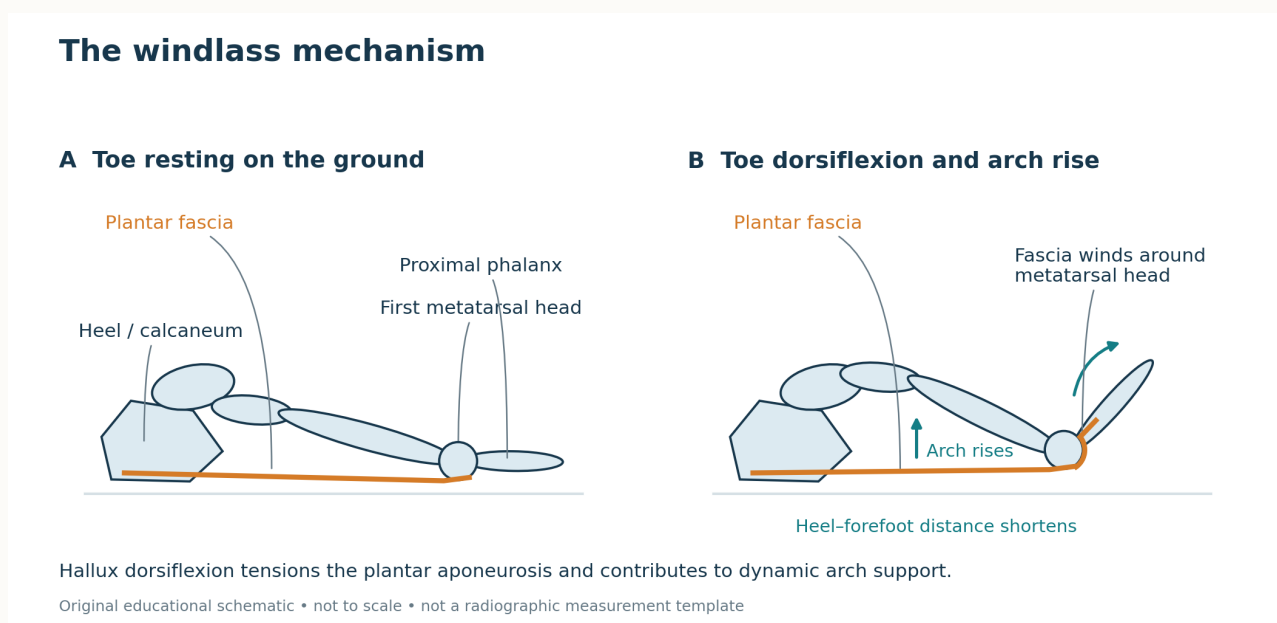


Figure 6.1 The windlass mechanism. Toe dorsiflexion winds the plantar aponeurosis around the metatarsal head. The drawing isolates the principle; a walking foot also experiences changing load, fascia stretch and muscle activity. [B1, B2, B3]

A useful mechanism within a dynamic system

The windlass explains an important relationship between toe movement and arch behaviour, but it is not the only source of stiffness during push-off. In a study of 25 healthy adults, static toe dorsiflexion raised the arch, whereas during walking the arch could initially descend despite toe dorsiflexion. Loading and tissue extensibility alter the relationship observed in a seated examination. [B2]

Experimental work also links increased push-off stiffness to active muscle contraction. The calf, intrinsic muscles, plantar fascia and metatarsophalangeal joints therefore need to be considered together. This does not make the windlass irrelevant; it places the passive mechanism within the functioning foot. [B3]

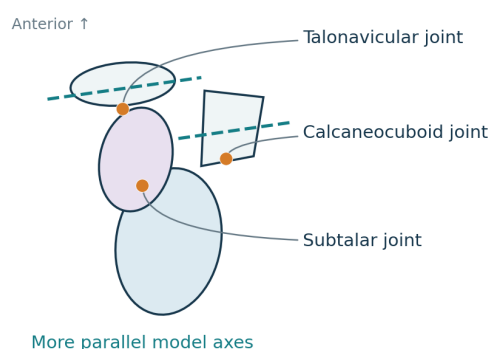
Clinically, hallux dorsiflexion should be assessed with attention to loading, first-ray position and pain. The standing Jack or Hubscher manoeuvre observes whether passive hallux dorsiflexion is accompanied by arch elevation. It is a component of assessment, not a complete simulation of gait or a sufficient diagnosis by itself. A restricted or painful hallux may compromise comfortable rollover, while a flexible arch may behave differently under greater dynamic demand.

Hindfoot adaptation and functional stiffening

The traditional description of “unlocking” and “locking” is intended to explain how the foot accommodates the ground early in stance and provides effective force transmission later. With loading, hindfoot eversion and coupled motion permit adaptation. As stance progresses, the foot commonly resupinates and muscle forces help support propulsion.

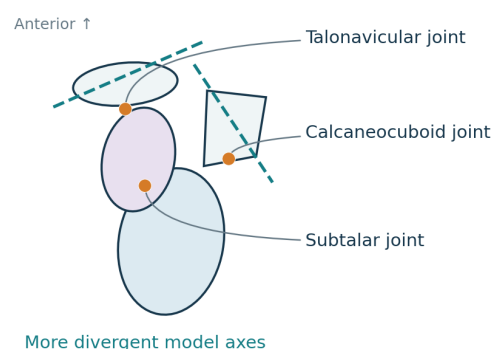
From ground adaptation to propulsion

A Pronation / adaptation



Classical conceptual model

B Supination / propulsion



Increasing functional stiffness; joints continue moving.

Original educational schematic • not to scale • not a radiographic measurement template

Figure 6.2 From adaptation to propulsion. The axis sketch is a classical conceptual model, not a measured representation of fixed anatomical hinges. Modern studies show continued midtarsal movement during late stance. [B5, B6]

The classical model associates a more parallel relationship of midtarsal axes with mobility and divergent axes with reduced mobility. It is helpful for introducing coordinated movement, but the joints do not suddenly become an immobile block. Cadaveric gait simulation found continued compliance despite divergent axes. In vivo skeletal tracking likewise demonstrated talonavicular and calcaneocuboid motion into terminal-stance supination. [B5, B6]

For clinical teaching, “increasing functional stiffness” is more precise than a literal mechanical lock. The subtalar joint, Chopart complex, plantar ligaments, fascia and

muscle activity all contribute. This coordination depends on loading and the task being performed.

Tibialis posterior helps control hindfoot and medial-column behaviour; the peroneals provide complementary control. A heel rise should be observed for elevation, balance, pain and the direction of heel movement. Failure of the heel to invert is relevant, but it must be interpreted with strength, tendon integrity and available joint motion. Pain, weakness and fixed deformity can produce superficially similar performances.

An arthritic or fused joint is a different state from physiological functional stiffening. It has restricted available motion throughout the task. The remaining joints and muscles must accommodate the altered mechanics, and this compensation may itself become symptomatic.

Muscle balance and control of the first ray

Extrinsic muscles originate in the leg and act through long tendons; intrinsic muscles lie within the foot. Their contribution depends on timing, strength, tendon continuity, joint position and the direction of the external load. Describing an isolated muscle action is useful, but the walking foot requires coordinated activity.

Muscle or group	Principal mechanical contribution	Clinical implication
Tibialis anterior	Dorsiflexion and inversion; foot positioning in swing and controlled lowering after contact	Weakness may cause foot slap or inadequate toe clearance
Tibialis posterior	Inversion and plantarflexion; control of hindfoot and medial arch behaviour	Assess resisted inversion, tenderness and heel-rise behaviour
Peroneus longus	Eversion and first-ray plantarflexion through its plantar course to the medial cuneiform and first metatarsal base	Helps maintain medial forefoot contact; imbalance may plantarflex the first ray
Peroneus brevis	Eversion and lateral stability through its fifth-metatarsal insertion	Weakness or tearing can impair control of inversion
Gastrocnemius and soleus	Control tibial progression and contribute ankle plantarflexor power	Weakness impairs progression; contracture can restrict dorsiflexion
Long toe flexors and extensors	Toe movement and supplementary ankle and foot control	Imbalance contributes to deformity and altered plantar loading
Plantar intrinsic muscles	Toe and metatarsophalangeal control, load-responsive stabilisation and propulsion	Evaluate toe posture, purchase, sensation and functional endurance

Tibialis anterior and peroneus longus attach on opposite aspects of the medial cuneiform and first-metatarsal base. Their effects on first-ray position are

complementary but not identical. Tibialis posterior supports inversion and medial-foot control; peroneus brevis provides an opposing eversion influence. A muscle may be structurally intact yet function ineffectively because its lever arm, activation or antagonist balance has changed.

Cadaveric work confirms that tibialis posterior and peroneus longus loading have different effects on arch mechanics. They should not be portrayed as interchangeable “arch raisers”. [B7] Experimental suppression of intrinsic muscle activity also impaired distal-foot stiffness and effective propulsion, supporting their functional importance even when the longitudinal arch remained comparatively resistant to high loads. [B4]

In fixed arthritis, strengthening cannot reverse cartilage loss or reliably correct a rigid bony deformity. Muscle balance nevertheless remains relevant to the joints that still move, the stability of a reconstruction and rehabilitation.

The whole limb and the mechanical environment

The foot is the contact between the body and the ground. Hip motion, pelvic control, knee alignment, tibial rotation and limb-length difference can all alter the way it is used. Equally, a stiff or deformed foot may induce compensations above the ankle. I therefore examine the knee and hip when the gait pattern or history suggests a proximal contribution.

Varus knee alignment may be accompanied by compensatory hindfoot valgus, and valgus knee alignment by the converse pattern, but this relationship is not universal. In a study of patients with knee osteoarthritis, static compensation at the hindfoot did not reliably normalise dynamic loading during walking. A standing photograph and a gait assessment answer different questions. [B9]

Body weight is one part of loading exposure. Walking distance, speed, occupation, repeated lifting, sport, fatigue and the capacity of the tissues to recover also matter. Longitudinal observational evidence links increasing body weight with greater midfoot pressure and foot-related limitation. It does not predict an identical response to weight change in every patient. [B10] The practical discussion should connect manageable changes in exposure with the patient's goals and health.

Footwear is part of the examination

Inspect the shoes the patient actually uses. Consider toe-box width, sole stiffness, heel height, cushioning, rocker position, fixation and the space available for an orthosis. Wear patterns are clues to repeated contact; they are not a reliable diagnosis in isolation. Ask whether pain changes between work shoes, trainers and barefoot walking.

A stiff sole or appropriately selected rocker can reduce the motion demanded from a painful forefoot joint. In people with first metatarsophalangeal osteoarthritis, orthoses and rocker footwear altered plantar pressure in different ways. This supports individual fitting and reassessment rather than assuming that any rocker is suitable for every patient. [B25]

Tissue capacity modifies the mechanical problem

Skin condition, circulation, sensation and bone quality influence how much load is safe and how well reconstruction may heal. Neuropathy may remove the warning provided by pain. Inflammatory disease can affect several joints and stabilising tissues. A hot, swollen neuropathic foot requires assessment for active Charcot neuroarthropathy rather than routine treatment as uncomplicated flexible flatfoot.

My aim is to identify modifiable contributors without reducing a complex disability to body weight, a shoe choice or a single alignment measurement. Mechanical treatment succeeds when it is feasible for the person who must use it.

Reduced arch and cavovarus patterns

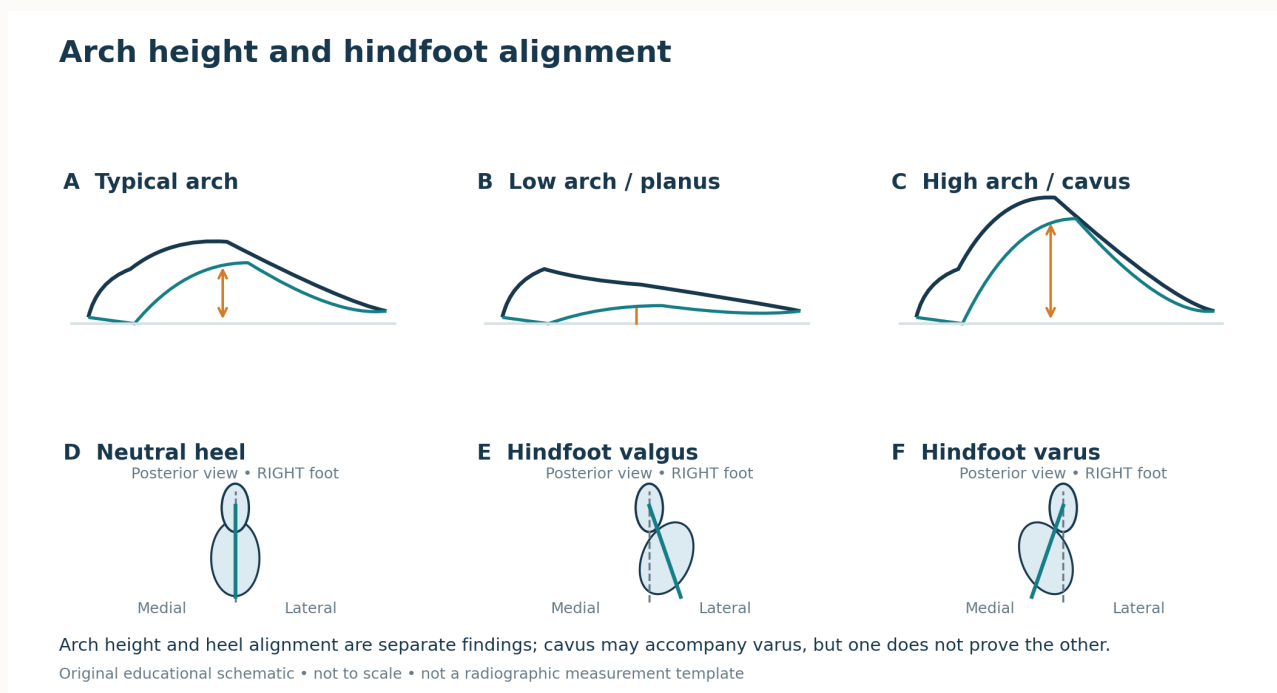


Figure 6.3 Arch height and heel alignment are separate observations. A low arch often accompanies valgus and a cavus arch may accompany varus, but these combinations are not inevitable. The panels depict common patterns, not diagnostic categories. [B11, B12, B13]

Planus and progressive collapsing foot deformity

An asymptomatic low arch is not automatically a disease. Progressive collapsing foot deformity describes an acquired three-dimensional disorder that may combine hindfoot valgus, forefoot abduction, medial-column instability, peritalar subluxation and ankle valgus. Tibialis posterior dysfunction may contribute, but failure of the spring or deltoid ligament and other structures also matters. It is not always a simple sequence beginning with tendon rupture. [B13] My patient information follows the same distinction between foot shape, symptoms and progressive structural failure. [B30]

The 2020 PCFD classification uses stage 1 for flexibility and stage 2 for rigidity, with classes A to E describing different deformity components. These stages should not be confused with the older Johnson-Strom/Myerson staging systems. Each component should be examined on its own merits. [B13]

Cavus and cavovarus

Cavus describes an elevated longitudinal arch. Cavovarus adds a varus heel and may include a plantarflexed first ray, forefoot adduction and clawing. Reduced contact area and lateral loading can accompany callosity, recurrent instability or peroneal symptoms. Some feet remain flexible; others become stiff. Progressive, asymmetric or bilateral deformity warrants a neurological history and examination. [B12]

A plantarflexed first ray can drive compensatory heel varus when the hindfoot remains mobile. Conversely, a primary hindfoot deformity can determine forefoot loading. Identifying which component drives the pattern is more useful than simply naming the arch “high”. The Coleman block test assists this distinction, but is interpreted together with manual correction and imaging. [B23] The aim is balanced loading and stability, with neurological progression considered when counselling about recurrence. [B31]

Forefoot adduction abduction and coronal compensation

Forefoot abduction is an outward relationship of the forefoot to the hindfoot. In a collapsing foot, lateral displacement at the talonavicular region can expose more of the medial talar head. The “too many toes” appearance from behind can support the observation, but camera position, whole-limb rotation and other deformities influence this sign.

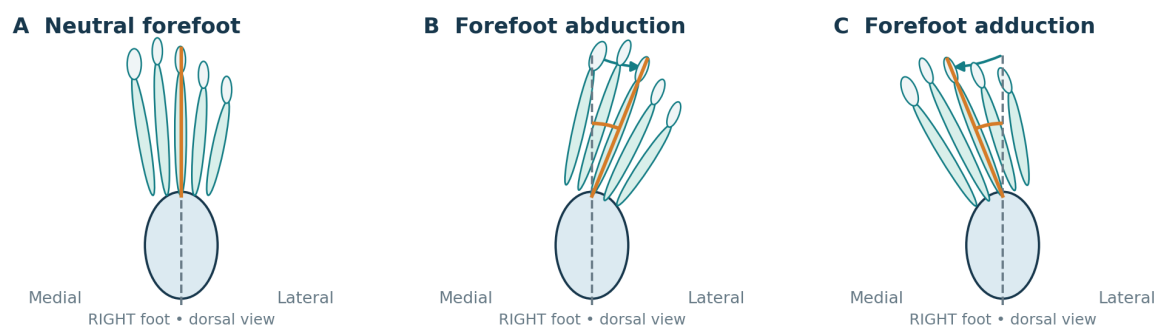
Forefoot adduction is an inward relationship. Metatarsus adductus specifically describes the metatarsal segment relative to the lesser tarsus. It should not be inferred solely from an inward foot-progression angle, which may arise from femoral version, tibial torsion or combined causes. [B15]

Coronal-plane forefoot varus or supination is a separate finding: the medial forefoot lies relatively elevated when the hindfoot is held in the chosen reference position. It may compensate for longstanding hindfoot valgus. Forefoot valgus describes the opposite coronal relationship. These terms should not be used as substitutes for transverse-plane adduction and abduction.

The first ray needs particular attention. After correcting the heel and hindfoot manually, determine whether the first metatarsal head can meet the ground without forcing the rest of the foot into a compensatory position. Residual medial forefoot elevation may prevent balanced contact; a plantarflexed first ray may create focal pressure and contribute to heel varus.

This explains why an isolated correction can leave an incompletely balanced foot. Treatment planning should identify the position of the heel, the alignment of the midfoot, the flexibility of the medial column and the final relationship of the metatarsal heads to the ground. The desired result is a comfortable plantigrade foot with load distributed through tissues able to tolerate it.

Forefoot abduction and adduction



Forefoot alignment is shown relative to a fixed hindfoot reference; this is not rotation of the whole lower limb.

Original educational schematic • not to scale • not a radiographic measurement template

Figure 6.4 Transverse-plane forefoot position in a right foot. Abduction moves the forefoot laterally relative to the hindfoot; adduction moves it medially. Rotating the entire limb is a different phenomenon. Schematic axes indicate direction rather than a clinical angle measurement.

A structured clinical assessment

The history should establish the location and timing of pain, progression of deformity, instability, fatigue, shoe difficulty and the activities the patient wants to regain. Ask about trauma, previous operations, neurological symptoms, inflammatory disease, diabetes and relevant family history. Separate pain during weight acceptance from pain during heel rise or toe rollover.

Standing and walking

Observe both limbs from the front, side and rear. Record arch shape, heel position, forefoot direction, toe deformity, callosity and the ability to stand comfortably. Compare natural standing with the position achieved by gentle correction. Then observe walking as described earlier under Gait analysis and the progression of load. A deformity should be described under load and in terms of how much it changes during movement.

Seated or supine examination

Palpate the symptomatic structures and assess ankle, subtalar, midtarsal and metatarsophalangeal motion separately. Test tibialis anterior, tibialis posterior, both peroneals, calf strength and toe function. Examine skin, pulses and sensation. Record the difference between pain-limited movement, a soft-tissue restriction and a firm structural block.

Functional and flexibility tests

During a supported single-leg heel rise, note the height, repetitions, pain, balance and heel inversion. Inability to perform it does not identify one tendon lesion by itself. The patient may have calf weakness, pain, impaired balance or a rigid hindfoot.

For the Coleman block test, support the heel and lateral forefoot while allowing the medial forefoot and first ray to hang free. Reduction of heel varus supports a flexible hindfoot with a forefoot-driven component. Persistent varus suggests a residual hindfoot contribution. A small weight-bearing CT study found improvement without complete correction in its adult cohort; the test should not be treated as an infallible binary surgical algorithm. [B23]

For the Silfverskiöld assessment, compare ankle dorsiflexion with the knee extended and flexed while controlling hindfoot and midfoot compensation. Improvement with knee flexion suggests an isolated gastrocnemius contribution. Persistent limitation may reflect the gastrocnemius-soleus complex, capsular restriction or a bony block. A technique study showed why movement through neighbouring joints must not be mistaken for tibiotalar dorsiflexion. [B24]

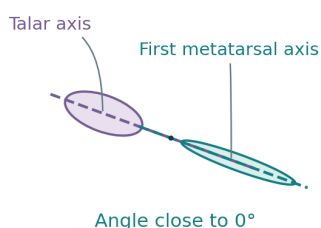
The standing windlass test complements these observations. Finally, correct the hindfoot and reassess the forefoot. This exposes residual supination, first-ray malposition or medial-column instability that might be missed when the foot is examined only in its habitual deformity.

Meary angle and the location of arch deformity

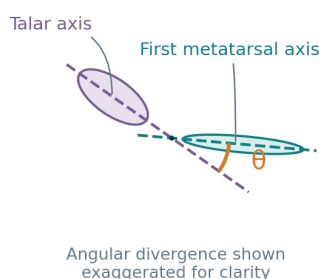
For alignment assessment, obtain weight-bearing dorsoplantar and lateral foot radiographs when the patient can safely stand. Add ankle and hindfoot alignment views when the examination requires them. The images should reproduce a documented stance with consistent positioning; an unloaded image may underrepresent collapse. [B15]

Meary angle: lateral talus-first metatarsal alignment

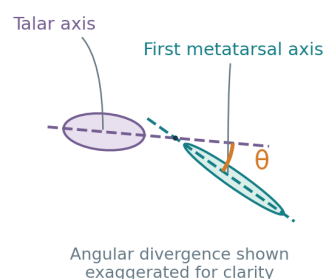
A Axes approximately collinear



B Flatfoot: apex plantar



C Cavus: apex dorsal



Use a weight-bearing lateral radiograph; conventions and reference ranges must be stated when reporting.

Original educational schematic • not to scale • not a radiographic measurement template

Figure 6.5 Lateral Meary angle. The angle is expressed here as deviation from collinearity between the talar axis and first-metatarsal shaft axis. Plantar apex indicates a planus pattern; dorsal apex indicates a cavus pattern. The illustrated deviations are teaching examples. [B15, B16]

Meary's angle measures the relationship of the talar longitudinal axis to the first-metatarsal shaft axis. In a near-collinear foot the deviation is close to zero. If the

talar axis descends more steeply than the first-metatarsal axis, the pattern is planus, with a plantar apex. If the first metatarsal is more plantarflexed relative to the talar axis, the pattern is cavus, with a dorsal apex.

The often-taught approximation of $0^{\circ} \pm 4^{\circ}$ is not an absolute adult disease boundary. Published adult control measurements show appreciable variation and overlap with symptomatic groups. Report direction and magnitude, the acquisition method and the clinical context rather than assigning disease from a threshold alone. [B16, B17]

The angle indicates overall sagittal malalignment but does not identify every contribution to it. Inspect the talonavicular, naviculocuneiform and first tarsometatarsal regions for the location of collapse, instability or arthritis. The apparent intersection of extended axes is not automatically the anatomical site requiring an osteotomy or fusion.

Do not confuse the lateral measurement with an AP talus-first metatarsal measurement. The latter describes transverse-plane alignment. The imaging plane and sign convention should always be stated, particularly when comparing preoperative and postoperative studies.

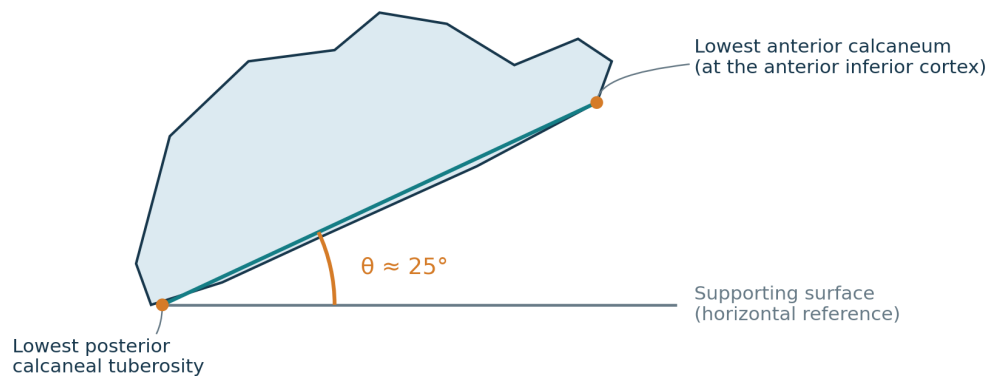
Calcaneal pitch and arch interpretation

Calcaneal pitch describes the inclination of the calcaneus relative to the ground. Approximately $20\text{-}30^{\circ}$ is a common teaching reference. A lower value supports reduced hindfoot height in many flatfoot patterns; a higher value supports increased inclination in many cavus patterns. Variation in population and measurement technique limits the value of a single universal boundary. [B15, B17]

Pitch and Meary's angle answer different questions. Pitch principally describes calcaneal orientation; Meary's angle relates the talus to the first ray. A foot with a markedly plantarflexed first ray may have an abnormal Meary angle without a proportionate increase in pitch. Conversely, the heel may be steep while the distal arch configuration contributes differently to symptoms.

The loading surface and chosen anterior endpoint must be visible. A different plantar reference line, rotated lateral projection or altered stance may change the result. The method should be kept consistent during serial assessment.

Calcaneal pitch



The pitch is the angle between the inferior calcaneal line and the supporting surface on a weight-bearing lateral image.

Original educational schematic • not to scale • not a radiographic measurement template

Figure 6.6 Calcaneal pitch. The inferior calcaneal reference line joins the plantar-most tuberosity to the inferior anterior calcaneum near the calcaneocuboid joint. Its angle to the supporting horizontal is measured on the weight-bearing lateral view. [B15, B17]

Measurement quality

Radiographic measurements are subject to observer variation. In an adult flatfoot reliability study, calcaneal pitch was more reproducible between observers than the talus-first metatarsal angle. Experience and consistent technique affected reliability. [B18] Small numerical differences between visits may therefore reflect measurement conditions rather than a meaningful biological change.

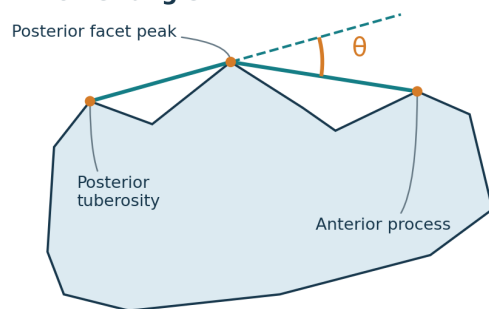
I interpret arch measurements alongside the patient's pain, callosity, gait and flexibility. The aim is to understand where the structure is failing to meet its mechanical demands. A number is useful when it helps answer that question; it is insufficient when detached from it.

Böhler angle and the angle of Gissane

These measurements describe the superior calcaneal profile, particularly in fracture assessment. They should be kept separate from the principal measurements of arch alignment.

Calcaneal morphology: Böhler and Gissane angles

A Böhler angle

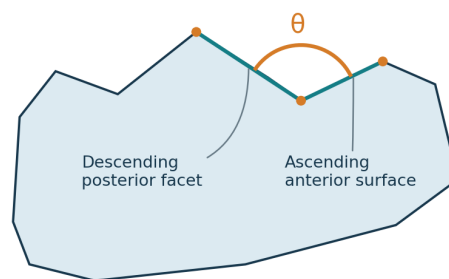


Acute angle shown $\approx 25^\circ$

These assess calcaneal shape, especially after trauma; they are distinct from measures of longitudinal arch alignment.

Original educational schematic • not to scale • not a radiographic measurement template

B Critical angle of Gissane



Internal angle shown $\approx 121^\circ$

Figure 6.7 Calcaneal morphology. Böhler's angle is the small angle between the extended reference lines through the three superior landmarks. Gissane's angle is the obtuse angle between the cortical slopes at the superior calcaneal sulcus. [B19, B20]

For Böhler's angle, identify the highest point of the posterior tuberosity, the highest point of the posterior facet and the highest point of the anterior process. Draw a line from the tuberosity to the posterior facet and another from that facet to the anterior process. Measure the small angle between their extended directions, not the large internal angle at the facet. Common adult teaching references are 20-40°, with AO describing approximately 25-40°. Depression of the posterior facet may reduce it. [B15, B19]

Gissane's angle is formed by the descending and ascending slopes of the superior calcaneal cortex at the sulcus between the posterior facet and anterior process. Published conventions differ: BOFAS gives 120-145°, whereas another clinical series cites an adult reference of 100-130°. The convention and landmarks must therefore accompany the value. Age and population also affect reference measurements. [B15, B20]

An apparently normal angle does not exclude every calcaneal fracture, and neither angle describes the complete three-dimensional injury. In displaced intra-articular fractures, observer reliability can be poor. CT provides additional information about articular displacement, fragments, width and hindfoot shape when indicated. [B22]

In the chronic setting, calcaneal malunion may affect heel height, width, alignment, subtalar congruity and shoe tolerance. The biomechanical assessment should identify these consequences rather than judge the patient's function solely by whether Böhler's angle has been restored.

Other measurements and three dimensional imaging

Talonavicular coverage is commonly assessed using lines joining the medial and lateral margins of the opposing articular surfaces. A research protocol in asymptomatic adults demonstrated that reference measurements can differ considerably from narrow textbook limits. It is better to describe the direction and extent of uncoverage, together with the rest of the deformity, than impose a universal cutoff. [B17]

The hindfoot alignment view provides a coronal relationship between the tibia and the heel. A heel located lateral to the tibial reference is valgus; medial displacement is varus. Saltzman and El-Khoury's original study established a reproducible method and demonstrated normal variation. Its observations are not universal operative correction targets. [B21]

Weight-bearing CT can clarify three-dimensional peritalar relationships, impingement and complex deformity under load. Conventional CT helps define bone and joint morphology; MRI and ultrasound answer different questions about soft tissues or other pathology. Selection depends on the uncertainty that remains after examination and radiographs.

For any serial comparison, record the side, loading condition, projection, endpoints and sign convention. Review the images themselves when the report and clinical picture conflict. An imaging measurement describes a component of the problem; it does not prescribe an operation.

Our work on CT-based motion analysis examined a digital method for measuring lower-leg rotational relationships by comparing three-dimensional bone models. It reflects my interest in measurements that address a precise reconstructive question. The study introduced and assessed a measurement technique; it did not establish a universal degree of rotation at which every patient benefits from an osteotomy. Suspected post-traumatic malrotation still requires a clinical explanation linking the measured difference to symptoms and function. [B28]

Measure or view	What it describes	Interpretive caution
AP talus-first metatarsal relationship	Transverse divergence of the talus and medial forefoot	State medial or lateral direction; first-ray deformity can distort the inference
Talonavicular coverage angle	Relationship of the talar-head and navicular articular margins	Increasing lateral uncoverage supports abduction; published reference limits vary
Metatarsus adductus angle	Second-metatarsal axis relative to the lesser-tarsus axis	Distinguish segmental adduction from whole-limb internal rotation
AP and lateral talocalcaneal angles	Relationship of talar and calcaneal reference axes in their respective projections	The projections are not interchangeable and do not fully describe hindfoot rotation
Standing hindfoot alignment view	Heel position relative to the tibial shaft or weight-bearing axis	Report medial or lateral offset in millimetres; do not confuse an offset with an angle
Ankle mortise or AP view	Talar position, tilt and joint-space relationship	A valgus heel does not establish ankle valgus or deltoid insufficiency

Translating biomechanics into treatment

The treatment plan should identify the painful structure, the source of abnormal load, the components that remain correctable and the patient's ability to undertake rehabilitation. My first question is what change will make walking more comfortable and sustainable. The answer may involve footwear, activity, exercise, an orthosis, reconstruction or treatment of an arthritic joint.

Nonoperative mechanical treatment

Footwear can provide space, cushioning or a more tolerable rollover. An orthosis may redistribute pressure and influence moments; a brace may reduce the demand on unstable or painful segments. The device should be matched to flexibility, skin tolerance, sensation, footwear and the patient's practical needs. A rigid deformity may require accommodation rather than forceful correction into an intolerable position. [B27]

Rehabilitation addresses the deficits demonstrated during assessment: calf capacity, ankle movement, tibialis posterior or peroneal function, toe control, balance and gait confidence. Progressive loading should be adjusted to symptoms and tissue condition. A painful, stiff joint and a weak but mobile foot require different objectives. The expected benefit should be explained in functional terms and reviewed against the patient's response.

A device prescription should state its intended effect. Is the aim to cushion a painful heel, unload a plantar prominence, limit a painful joint, improve stability or accommodate a fixed shape? This makes reassessment useful. If the patient is more

comfortable but cannot wear the device at work, the treatment has an implementation problem. If the device fits but moves pain to another part of the foot, the distribution of load needs review. The successful orthosis is the one that helps the patient function within their daily environment, rather than the one whose shape appears most corrective on the examination bench.

The same reasoning applies after surgery. A reconstructed foot has to learn to accept load again. Walking distance, calf endurance, balance and confidence may improve at different speeds. A technically successful operation therefore requires a plan for progressive activity, suitable shoes and review of persistent compensations. Rehabilitation should neither force movement through a joint intended to fuse nor leave all neighbouring joints unnecessarily inactive.

Joint preservation and reconstruction

Where joints remain usable and deformity is correctable, osteotomy, selective soft-tissue reconstruction and tendon balancing may redistribute load while preserving motion. The plan must address each important plane of deformity. Correcting heel valgus while leaving forefoot supination or medial-column instability may fail to establish balanced ground contact.

Tendon transfer or repair should work within a corrected mechanical environment. A reconstructed tendon should not be expected to hold an uncorrected structural deformity indefinitely. Equally, correcting bone alignment while ignoring persistent muscle imbalance may leave a risk of recurrent abnormal loading.

Rigid deformity and arthritis

When a joint is painful, structurally damaged and rigid, a fusion may provide a stable platform and relieve pain by eliminating motion at that joint. The position of fusion and the condition of neighbouring joints matter because the remaining motion and loading are redistributed. The PCFD operative consensus prioritises a stable, properly aligned foot while favouring preservation of movement where it remains appropriate. [B14]

Muscle balance does not cease to matter once arthritis develops. Its role changes: it may be insufficient to correct the established deformity, but it continues to influence walking, residual joint function and recovery. This distinction preserves the value of biomechanics throughout the course of disease.

Bringing the findings together

The following examples illustrate reasoning, not records of individual patients.

A painful flexible collapsing foot

Medial pain, hindfoot valgus and forefoot abduction suggest a connected problem. Examine tibialis posterior, the heel-rise response, medial-column stability and residual forefoot position after correction. Relate weight-bearing images to the symptomatic joints. A flexible deformity with preserved joint surfaces raises different treatment possibilities from a stiff arthritic foot with a similar outline. [B11, B13, B14]

A high arch with lateral symptoms

Determine whether the heel varus improves when the plantarflexed first ray is unloaded. Assess peroneal strength, lateral ligament stability, callosity and neurological function. The purpose is to distinguish a forefoot-driven component from a persistent hindfoot deformity and to identify the tissues exposed to excessive load. [B12, B23]

Painful propulsion with a relatively normal arch

A patient may have an acceptable arch profile but painful hallux rollover, calf weakness or limited ankle dorsiflexion. Investigate the phase of gait that reproduces symptoms. A normal Meary angle does not exclude a clinically important mechanical problem, and arch correction is not the automatic answer.

A stiff arthritic foot

Identify which joints are painful, which still move and where compensation occurs. Assess shoe requirements, walking distance and the patient's priorities. The decision to preserve or sacrifice movement should be linked to its usefulness, pain and the stability obtainable through treatment. [B14]

The surgeon's synthesis

Before recommending an intervention, I should be able to explain the diagnosis in a connected sentence: where the pain arises, how load reaches that structure, which deformity is primary or compensatory, and what the proposed treatment is expected to change. If that explanation is uncertain, further assessment should answer the uncertainty.

The essential lesson is that foot biomechanics remains relevant from the first consultation to the final stage of rehabilitation. Gait, alignment, muscle balance, tissue health and radiographic measurements are different views of the same functioning limb. Their value lies in bringing them together for the patient.

I judge the final reconstruction through both structure and experience. The radiograph can show that a fusion has united or an osteotomy has corrected alignment. The patient tells me whether the foot remains painful at the end of the day, whether stairs are manageable and whether ordinary shoes can be worn. These outcomes should be recorded together. The philosophy of biomechanics is completed when anatomical reasoning produces a practical improvement in the patient's life.

Further reading within the book

The preceding chapters on the hindfoot, midfoot and forefoot discuss the regional conditions to which these principles apply. This chapter provides the mechanical framework for interpreting those conditions and explaining treatment choices.

References for Chapter 6

[B1] Hicks JH. The mechanics of the foot II The plantar aponeurosis and the arch. *Journal of Anatomy*. 1954;88:25-30. [Read source](#)

[B2] Sighting F, Ebrecht F. The rise of the longitudinal arch when sitting standing and walking Contributions of the windlass mechanism. *PLoS One*. 2021;16:e0249965. [Read source](#)

- [B3]** Farris DJ, Birch J, Kelly L. Foot stiffening during the push-off phase of human walking is linked to active muscle contraction and not the windlass mechanism. *Journal of the Royal Society Interface*. 2020;17:20200208. [Read source](#)
- [B4]** Farris DJ, Kelly LA, Cresswell AG, Lichtwark GA. The functional importance of human foot muscles for bipedal locomotion. *PNAS*. 2019;116:1645-1650. [Read source](#)
- [B5]** Phan CB, Shin G, Lee KM, Koo S. Skeletal kinematics of the midtarsal joint during walking Midtarsal joint locking revisited. *Journal of Biomechanics*. 2019;95:109287. [Read source](#)
- [B6]** Okita N, Meyers SA, Challis JH, Sharkey NA. Midtarsal joint locking New perspectives on an old paradigm. *Journal of Orthopaedic Research*. 2014;32:110-115. [Read source](#)
- [B7]** Kokubo T, et al. Effect of the posterior tibial and peroneal longus on the mechanical properties of the foot arch. *Foot and Ankle International*. 2012;33:320-325. [Read source](#)
- [B8]** Venkadesan M, et al. Stiffness of the human foot and evolution of the transverse arch. *Nature*. 2020;579:97-100. [Read source](#)
- [B9]** Rühling M, Kirschbaum S, Perka C, Graef F. Functional gait analysis reveals insufficient hindfoot compensation for varus and valgus osteoarthritis of the knee. *International Orthopaedics*. 2023;47:1233-1242. [Read source](#)
- [B10]** Walsh TP, et al. Increase in body weight over a two-year period is associated with an increase in midfoot pressure and foot pain. *Journal of Foot and Ankle Research*. 2017;10:31. [Read source](#)
- [B11]** British Orthopaedic Foot and Ankle Society. Hyperbook Pes Planus. Professional educational resource. [Read source](#)
- [B12]** British Orthopaedic Foot and Ankle Society. Hyperbook Cavovarus Foot. Professional educational resource. [Read source](#)
- [B13]** Myerson MS, et al. Classification and Nomenclature Progressive Collapsing Foot Deformity. *Foot and Ankle International*. 2020;41:1271-1276. Consensus statement. [Read source](#)
- [B14]** Sangeorzan BJ, et al. Progressive Collapsing Foot Deformity Consensus on Goals for Operative Correction. *Foot and Ankle International*. 2020;41:1299-1302. Consensus statement. [Read source](#)
- [B15]** British Orthopaedic Foot and Ankle Society. Hyperbook Part 2 Anatomical Alignment. Professional educational resource. [Read source](#)
- [B16]** Younger AS, Sawatzky B, Dryden P. Radiographic assessment of adult flatfoot. *Foot and Ankle International*. 2005;26:820-825. [Read source](#)
- [B17]** Murley GS, Menz HB, Landorf KB. A protocol for classifying normal- and flat-arched foot posture for research studies using clinical and radiographic measurements. *Journal of Foot and Ankle Research*. 2009;2:22. [Read source](#)
- [B18]** Sensiba PR, et al. Inter- and intraobserver reliability in the radiographic evaluation of adult flatfoot deformity. *Foot and Ankle International*. 2010;31:141-145. [Read source](#)
- [B19]** AO Foundation. AO Surgery Reference Displaced fracture of the calcaneus body. Professional educational resource. [Read source](#)
- [B20]** Boyle MJ, et al. The paediatric Bohler's angle and crucial angle of Gissane a case series. *Journal of Orthopaedic Surgery and Research*. 2011;6:2. [Read source](#)
- [B21]** Saltzman CL, El-Khoury GY. The hindfoot alignment view. *Foot and Ankle International*. 1995;16:572-576. [Read source](#)
- [B22]** Otero JE, et al. There is poor reliability of Böhrer's angle and the crucial angle of Gissane in assessing displaced intra-articular calcaneal fractures. *Foot and Ankle Surgery*. 2015;21:277-281. [Read source](#)
- [B23]** Foran IM, et al. Impact of Coleman Block Test on Adult Hindfoot Alignment Assessed by Clinical Examination, Radiography, and Weight-Bearing Computed Tomography. *Foot and Ankle Orthopaedics*. 2020;5(3):2473011420933264. [Read source](#)
- [B24]** Goss DA Jr, Long J, Carr A, Rockwell K, Cheney NA, Law TD Sr. Clinical Implications of a One-hand Versus Two-hand Technique in the Silfverskiöld Test for Gastrocnemius Equinus. *Cureus*. 2020;12(1):e6555. [Read source](#)
- [B25]** Menz HB, Auhl M, Tan JM, Levinger P, Roddy E, Munteanu SE. Biomechanical Effects of Prefabricated Foot Orthoses and Rocker-Sole Footwear in Individuals With First Metatarsophalangeal Joint Osteoarthritis. *Arthritis Care and Research*. 2016;68(5):603-611. [Read source](#)
- [B26]** Dubo HI, et al. Electromyographic temporal analysis of gait normal human locomotion. *Archives of Physical Medicine and Rehabilitation*. 1976;57:415-420. [Read source](#)

[B27] British Orthopaedic Foot and Ankle Society. Hyperbook The Functional Role of Orthotic Devices in the Foot and Ankle. Professional educational resource. [Read source](#)

[B28] Bakhshayesh P, Ihediwa U, Sandher S, Vris A, Heidari N, Enocson A. A novel technique to assess rotational deformities in lower extremities using CT-based motion analysis. Scientific Reports. 2021;11:21123. [Read source](#)

[B29] Bakhshayesh P. Leeds Ankle and Foot Surgery. About us. Author professional website. [Read source](#)

[B30] Bakhshayesh P. Progressive collapsing foot deformity. Author patient information. Prepared 10 October 2026. [Read source](#)

[B31] Bakhshayesh P. Cavovarus and high arched foot. Author patient information. Prepared 10 October 2026. [Read source](#)

CHAPTER 07

07 Sports injuries tendons and return to activity

The philosophy of treating the injured athlete

The starting point in sports injury is to understand the person, the movement and the tissue that has failed. A painful foot cannot be interpreted in isolation from the limb above it, the athlete's training, footwear, body weight, recovery and expectations. The purpose of treatment is to restore a foot that can accept load, adapt to the ground and generate an effective push-off. A comfortable examination room assessment is only one part of that task.

This chapter addresses tendinopathy, ligament injury, osteochondral lesions of the talus, plantar fasciopathy, Haglund-related posterior heel pain, turf toe and lesser metatarsophalangeal plantar plate injury. It is intended for clinicians and learners. The clinical principles also apply to recreational activity and physically demanding work; an athlete need not compete professionally to experience a significant loss of function.

In the approach developed throughout this book, biomechanics is central. Observe how the patient stands and walks. Examine the hip and knee when their movement or alignment contributes to the presentation. Consider hindfoot position, arch behaviour, calf strength, first-ray function, hallux motion and the balance between the tibial and peroneal tendons. These observations guide treatment, but no single foot posture proves the cause of pain. Findings must agree with the history, local examination and functional limitation.



Sports injury care of the foot and ankle. Original AI-assisted editorial artwork; no real patient is depicted.

Injury and capacity

An acute event may exceed the strength of a ligament, plantar plate or osteochondral surface. Repeated loading may exceed a tendon or fascia's capacity to recover. The two mechanisms can coexist: an ankle sprain may reveal a previously overloaded peroneal tendon, while a fatigued athlete may sustain an acute tear. Establishing this sequence helps explain why treating only the most visible abnormality can leave the patient symptomatic.

We should distinguish reversible pain and weakness from mechanical instability, a displaced fragment or a substantial rupture. An uncomplicated tendon overload problem usually needs progressive loading. An unstable joint or displaced osteochondral injury may need protection and early specialist intervention. The same instruction to “exercise through it” is therefore inappropriate across all sports injuries. [S1, S2, S8, S11, S13, S14, S15, S16, S17, S18]

What constitutes a successful result

Success should be defined with the patient: walking without a limp, completing a working day, returning to running, or recovering the acceleration and cutting demanded by a particular sport. Pain relief matters, but so do strength, confidence, movement quality and the response to repeated sessions. Surgery can repair or reconstruct a structure; rehabilitation develops the capacity to use it.

For the surgeon, an important discipline is to separate the repairable lesion from the wider loss of capacity. A repaired ligament may restore restraint, yet the athlete may

remain hesitant when landing. A quiet tendon at rest may still be unable to tolerate successive training days. I therefore regard the operation, where required, as one stage of a larger recovery process whose final test is function outside the clinic.

Assessment and diagnostic reasoning

Ask how symptoms began, where the patient first felt them and whether they could continue activity. A pop, immediate swelling, inability to push off, locking or visible deformity changes the diagnostic priority. In gradual presentations, review recent changes in distance, speed, hills, jumping, surface, footwear and recovery. Ask about previous sprains, treatment adherence, work demands, smoking, diabetes, inflammatory disease and relevant medicines, including fluoroquinolones or corticosteroids.

Examine both limbs with the patient standing and sitting. Record gait, swelling, skin condition, focal tenderness, range of movement, tendon continuity, resisted strength and neurovascular status. Add single-leg balance, heel-rise testing and controlled squat or step tasks when safe. Progress to hopping or sport-specific testing only after fracture, rupture and significant instability have been considered. Re-examination after acute pain settles can clarify initially guarded ligament tests.

Table 7.1. Patterns guide investigation; they do not establish a diagnosis alone.

Pattern	Useful clinical clue	Important alternative
Tendon overload	Local pain with resisted or repeated loading	Partial or complete rupture; instability
Ligament injury	Twisting event, swelling or giving way	Fracture; syndesmosis; associated cartilage injury
Osteochondral lesion	Deep pain, swelling after activity, catching	Impingement; synovitis; occult fracture
Plantar heel pain	First-step pain and medial heel tenderness	Stress injury; nerve or heel-pad pain
Plantar MTP pain	Painful push-off, loss of toe purchase or instability	Sesamoid fracture; synovitis; neuroma

Choosing imaging

Use radiographs for suspected fracture, alignment, joint congruity, sesamoid position or a bony prominence; weight-bearing views are useful when tolerable and clinically appropriate. Apply validated acute ankle and foot radiograph decision rules within their intended setting. Normal radiographs do not exclude a stress injury, osteochondral lesion or plantar plate tear. Ultrasound can assess tendons and fascia dynamically; MRI is useful for marrow, cartilage and complex soft-tissue pathology. CT defines bony defects and fragment geometry. Order the study that resolves a clinical question. [S8, S11, S14, S15, S16, S17, S18]

Findings that require prompt escalation

Open injury, neurovascular compromise, a displaced joint, suspected infection or rapidly increasing pain and swelling require urgent assessment. A sudden loss of plantarflexion strength with a positive calf-squeeze test suggests Achilles rupture. Persistent focal bony pain, inability to bear weight, plantar midfoot bruising or a locked joint should prompt reassessment for an occult fracture, Lisfranc injury or displaced fragment. New painful calf swelling requires prompt assessment for deep vein thrombosis; new breathlessness or chest pain requires urgent assessment for possible pulmonary embolism, particularly during immobilisation.

Tendinitis and tendinopathy

Tendinitis is a familiar term, but persistent activity-related tendon pain is usually better described as tendinopathy. This terminology avoids assuming that inflammation alone explains the disorder. Tendon pain, structural change and functional capacity do not correlate perfectly: an abnormal scan may persist after clinical improvement, and a striking image does not by itself establish the need for surgery. [S1, S2]

Achilles tendon

Midportion symptoms occur above the calcaneal attachment, commonly with morning stiffness and pain during running or repeated heel rises. Insertional symptoms are centred within approximately 2 cm of the attachment. Examine the tendon, paratenon, bursae and adjacent structures, and assess calf endurance with the knee straight and bent. A sudden change in pain or loss of function requires assessment for a partial or complete tear. [S1, S2]

For uncomplicated midportion tendinopathy, education and progressive calf loading are foundational. Reduce the activities that repeatedly provoke a substantial flare while maintaining tolerable conditioning. A programme can move from supported or bilateral calf work to heavier unilateral resistance and later elastic tasks such as hopping. Eccentric exercise is one option; it is not the only effective way to load a tendon. Progression should reflect symptoms, strength and the next-day response. [S1]

Insertional disease needs particular attention to compression between tendon and calcaneus. Initially perform calf raises on level ground and avoid forcing the heel below the forefoot or repeatedly stretching into painful dorsiflexion. Temporary heel lifts may help. A 2025 randomised trial supports reducing compression during rehabilitation, although its small sample does not establish a single protocol for every patient. [S3]

Other tendons around the ankle

Peroneal pain lies behind or below the lateral malleolus and may follow a sprain. Resisted eversion, local palpation and assessment for snapping help distinguish tendinopathy from a split tear or instability. Dynamic ultrasound is particularly useful for intermittent tendon displacement. Significant tears or acute dislocation need a different pathway from uncomplicated overload. [S8]

Tibialis posterior symptoms behind the medial malleolus should prompt examination of heel-rise performance, arch behaviour and hindfoot position. Tibialis anterior pain may

be reproduced by resisted dorsiflexion; weakness or a tendon gap raises concern for rupture. Flexor hallucis longus symptoms may accompany repetitive pointe work or forceful push-off. These patterns direct examination rather than replacing it. Consider nerve pain, stress injury and joint disease when the findings do not agree.

A tendon examination becomes more informative when the relevant movement is observed. Snapping that occurs only with active circumduction may be absent during static palpation. A patient who can perform one heel rise may nevertheless have poor endurance or fail to bring the heel into the expected position. These observations should be recorded alongside symptoms so that progress can be judged against the same task at review. [S8]

Haglund heel and insertional Achilles disease

Haglund morphology describes a prominence of the posterosuperior calcaneus. Symptoms may arise from shoe-counter pressure, retrocalcaneal bursitis, insertional Achilles disease or a combination. A prominence on a radiograph is not, by itself, a painful syndrome or an indication for removal. Identify the symptomatic structure and relate it to the patient's footwear and activity. [S2, S9]

Start with footwear that reduces posterior pressure, appropriate temporary heel lifts and a progressive loading programme that limits painful insertional compression. Assess training load and calf capacity. Shockwave treatment does not remove the bony prominence, and a recent sham-controlled trial found no added benefit of radial shockwave over exercise and education for insertional tendinopathy. [S3, S5]

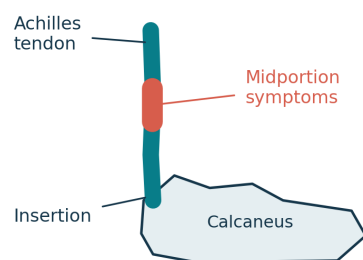
Persistent disabling symptoms despite a sustained, well-performed programme warrant reassessment. Operative options may include bursectomy, removal of impinging bone and debridement of diseased tendon. Reattachment or augmentation depends on tendon involvement and tissue quality. The procedure and recovery plan must reflect what is actually repaired; simple decompression and substantial tendon reconstruction are not interchangeable operations. [S9]

Consent includes wound problems, infection, nerve symptoms, persistent pain, weakness and possible reoperation. Plan the period of protection, thrombosis risk assessment, transport and work arrangements before operating. A patient who understands the rehabilitation commitment is better placed to choose between continued non-operative care and surgery.

HEEL PAIN: LOCALISE THE STRUCTURE

A Achilles midportion

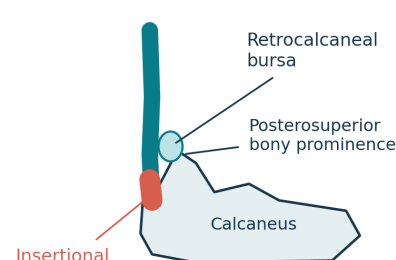
Sagittal schematic • posterior left



Pain above the attachment

B Insertion and Haglund

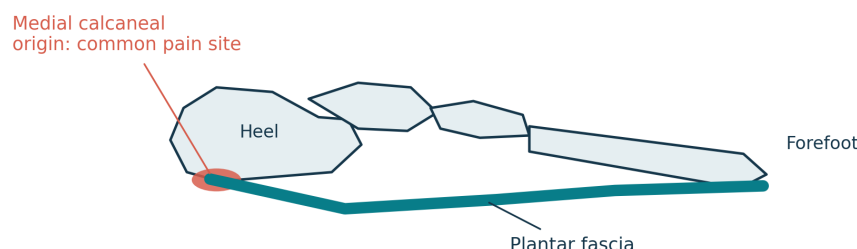
Sagittal schematic • posterior left



These findings can coexist

C Plantar fascia origin

Medial sagittal schematic • heel left



Original educational schematics • not to scale • symptom sites are illustrative, not diagnostic

Figure 7.1. Heel pain can arise above the Achilles insertion, at the insertion and adjacent bursa, or beneath the heel at the plantar fascia origin. These are distinct clinical problems. Simplified schematics; not to scale. [S2, S6, S9]

Achilles tendon rupture and restoration of push off

An acute Achilles rupture is a failure of the connection between the calf and the heel. The patient may describe an unexpected blow to the back of the ankle during acceleration, a sudden pop, or immediate loss of effective push-off. It can occur during recreational exercise or ordinary activity. The capacity to move the foot downwards does not exclude rupture: other plantarflexors may still produce movement while the principal Achilles mechanism has failed. The important clinical question is whether tendon continuity and effective calf-to-heel force transmission remain intact. [S24, S27]

Examine the resting position of both ankles, palpate for a defect and perform a calf-squeeze test with appropriate positioning. Acute swelling can obscure the gap, and delayed presentation can be deceptive because scar occupies the interval. Ultrasound is useful when the diagnosis, tear location or degree of disruption remains uncertain. Radiographs are appropriate when an avulsion or other bony injury is suspected. Imaging should resolve uncertainty without delaying protection of an evident rupture. [S24, S27]

Prompt protection in a plantarflexed position and referral into a recognised Achilles pathway are central. The exact splint or boot, permitted loading and subsequent adjustment must follow the treating service's protocol. A boot is a treatment device

whose position and fit matter, rather than a generic walking aid. The patient needs explicit instructions about wearing it, skin checks, falls prevention and seeking review. Thromboembolic and bleeding risks require individual assessment during lower-limb immobilisation. [S24, S28]

The principal options for an acute closed rupture are functional non-operative treatment and surgical repair followed by rehabilitation. Shared decision-making should consider the injury, delay to presentation, skin and vascular condition, general health, sporting and occupational demands, and the patient's ability to follow the rehabilitation programme. Surgery may reduce rerupture risk in some populations, but adds wound, infection and nerve risks. Neither pathway can dispense with rehabilitation. [S24, S25, S26]

A Norwegian randomised trial enrolled 554 adults and analysed 526. At twelve months, patient-reported Achilles function and physical performance were similar after non-operative treatment, open repair and minimally invasive repair. Rerupture occurred in 6.2% of the non-operative group and 0.6% in each surgical group; nerve injuries were reported more often after surgery, particularly the minimally invasive approach. These trial results support an informed discussion of different risks, rather than a promise that one pathway guarantees better function for every patient. They are trial estimates, not an individual prediction. [S25]

The UKSTAR trial provides a separate lesson about non-operative rehabilitation. Among 540 participants, an early functional brace produced similar nine-month Achilles function to plaster casting. Rerupture was reported in 5% of the brace group and 6% of the cast group. Functional bracing is therefore an evidence-supported option within a supervised protocol; this does not justify unsupervised removal of protection or unrestricted stretching during healing. [S26]

Different decisions in Achilles rupture care

Decision	What it addresses	What remains necessary
Non-operative functional treatment	Healing with protected positioning and staged loading	Reliable adherence and supervised rehabilitation
Open or minimally invasive repair	Approximation and repair of tendon ends	Wound monitoring and the same biological healing process
Chronic reconstruction	A gap, elongation or poor tissue unsuitable for straightforward repair	Assessment of donor consequences and extended rehabilitation

My emphasis is on restoring a useful muscle-tendon unit. Continuity alone is insufficient if the tendon heals elongated and the patient cannot produce an effective heel rise. Rehabilitation must respect healing while gradually recovering calf strength, endurance, control and elastic function. Progress is assessed through the quality and repetition of tasks, as well as pain and confidence. The person who walks comfortably may still lack the capacity for sprinting, jumping or a prolonged shift on their feet. [S29]

With a delayed or chronic rupture, the problem changes. Retraction, scar, tendon elongation and calf weakness can make direct repair inadequate. Selected patients may be managed with bracing and compensatory strengthening; others may require advancement, a tendon transfer such as flexor hallucis longus, or graft reconstruction. The choice depends on the defect, tissue quality, function and operative risk. A transfer also has consequences at its donor site, which belong in the consent discussion. [S27]

Recovery is measured in months, and higher-demand sport often requires a longer progression than the patient initially expects. Return decisions should examine calf strength and heel-rise performance, repeated loading tolerance, movement quality and sport-specific demands. The same standard applies after surgical and non-operative care: the patient should be able to perform the intended task safely and repeatedly, within the restrictions of the treating team. [S29]

Plantar fasciitis and plantar fasciopathy

Typical plantar fasciopathy causes plantar-medial heel pain, especially during the first steps after rest, with local tenderness near the medial calcaneal origin. Running, prolonged standing and a recent change in loading may aggravate it. The plantar fascia participates in arch support and the windlass mechanism: hallux dorsiflexion tensions the fascia during late stance. Persistent symptoms should be considered within this mechanical context, rather than attributed automatically to a radiographic heel spur. [S6, S19]

Confirm the pain generator

Examine calf flexibility, ankle dorsiflexion, plantar fascia tenderness, heel-pad tenderness and the response to gentle hallux dorsiflexion. Burning, tingling, diffuse rest pain or focal bony tenderness may point elsewhere. Important alternatives include calcaneal stress injury, heel-pad pain, nerve entrapment, inflammatory enthesitis and referred pain. Sudden pain with bruising or a pop suggests a tear. Imaging is most useful for an atypical presentation, failure to improve as expected or suspected alternative pathology. [S6, S19]

Restore tolerance to standing and push-off

Explain that improvement usually takes time and that complete inactivity may reduce conditioning. Adjust running and standing exposure to a tolerable level. Combine plantar-fascia-specific and calf stretching with progressive foot and ankle strengthening. Manual therapy can address relevant mobility restrictions; taping may provide short-term support. Foot orthoses can assist an overall programme but should not be presented as a stand-alone cure. A one-to-three-month night-splint trial can be considered when first-step morning pain remains consistent. [S6]

Review how the patient responds during exercise, later that day and the next morning. The aim is an improving trend in walking and activity tolerance. An orthosis should make practical sense in the patient's actual shoes. Discuss body weight sensitively where relevant, together with activity, nutrition and achievable goals; an individual should not be denied rehabilitation because their weight has not changed.

Persistent symptoms

Before escalating, reassess the diagnosis and the quality and duration of rehabilitation. Extracorporeal shockwave therapy can be discussed for persistent symptoms, with clear explanation of uncertain benefit. UK NICE guidance requires special arrangements for clinical governance, consent and audit or research. [S10]

Corticosteroid may give short-term relief, but it is not a durable solution for every patient. Discuss fascia rupture, fat-pad injury and the risks of repeated injection. PRP evidence varies with the comparator and preparation; it should not be promised as reliable tissue regeneration. Surgery is reserved for selected refractory cases and must address the clinical problem. Excessive fascial release can disturb arch mechanics. [S7, S19]

Lateral ankle ligament injury

An inversion injury, often with plantarflexion, commonly injures the anterior talofibular ligament; a more extensive injury may involve the calcaneofibular ligament. Pain and swelling alone do not describe the full injury. Look for malleolar or fifth-metatarsal fracture, peroneal injury, syndesmotic damage and an osteochondral lesion when the mechanism or recovery is atypical. [S11]

Examine tenderness and swelling, weight-bearing ability and neurovascular status. Anterior drawer and talar tilt testing contribute to assessment, but pain and guarding can limit their value immediately after injury. Compare with the opposite ankle and re-examine when appropriate. A previous history of giving way, generalised laxity or cavovarus alignment can influence both rehabilitation and later operative planning.

Early management

For a stable lateral sprain, protection with a suitable brace or tape, progressive weight bearing and structured exercise support recovery. A short period of immobilisation, up to about ten days, may help a severe injury; prolonged routine immobilisation is not the default. Analgesia, compression and elevation can make movement more comfortable. Treatment must be adjusted if fracture, unstable syndesmosis or another significant injury is present. [S11]

Rehabilitation develops range of movement, calf and peroneal strength, balance, landing control and confidence in changes of direction. Include the hip and knee when weakness or movement control affects the task. A brace can reduce recurrence risk in relevant sports, but it cannot replace restoration of strength and sensorimotor control. [S11]

Chronic instability

Recurrent giving way can reflect mechanical ligament insufficiency, impaired neuromuscular control or both. Ask which activities provoke instability and whether pain, swelling or locking accompanies it. Persistent symptoms require reassessment for impingement, peroneal pathology and cartilage injury rather than indefinite repetition of the same exercises.

Consider stabilisation when disabling instability remains despite an adequate rehabilitation programme and the examination supports a correctable mechanical problem. An anatomic repair, often a modified Broström-Gould procedure, may be suitable when tissue quality permits. Augmentation or graft reconstruction is considered in selected cases of inadequate tissue, revision surgery or other relevant factors. Address associated pathology and meaningful alignment problems within the overall plan. [S11, S20]

The operative aim is stability without unnecessary loss of movement. Discuss stiffness, nerve injury, wound problems, residual instability and the time required to regain sport-specific function. A mechanically stable ankle still needs rehabilitation to become a capable sporting ankle.

Pain and instability should be recorded separately. A patient may feel secure in a brace yet continue to develop deep joint pain after activity; another may have little pain but repeated unpredictable giving way. This distinction helps determine whether treatment should concentrate on ligament restraint, sensorimotor recovery, a coexisting osteochondral lesion or several problems together. The presence of one diagnosis must not make us stop examining the rest of the ankle. [S11, S20]

Syndesmosis and medial ligament injuries

A syndesmotic or high ankle sprain often follows external rotation with the foot planted. Pain may extend above the joint and be reproduced by external rotation or squeeze testing, but no single clinical test reliably settles every case. Examine the entire fibula and look for associated medial injury or fracture. Radiographs, selected stress or weight-bearing assessment and MRI can help define the problem. [S13]

The key treatment distinction is stability. A stable injury may be managed with protection followed by a planned progression of movement, loading and strength. An unstable syndesmosis needs specialist consideration of reduction and stabilisation. Do not transfer a routine lateral-sprain loading timetable to this injury without confirming stability. [S13]

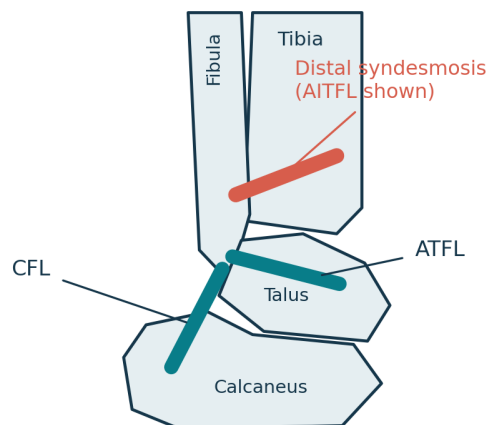
Medial pain after an eversion or external-rotation injury may involve the deltoid ligament. It should prompt a search for accompanying fracture, syndesmotic or lateral ligament injury. Mortise congruity and functional stability matter more than an isolated abnormal MRI description. The need for deltoid repair depends on the overall injury and remaining instability; routine repair of every acute tear is not established. [S21]

Deep joint pain, recurrent swelling or catching after an apparent sprain should raise suspicion of osteochondral injury. Ligament and cartilage problems can coexist, and treating only one may leave the other symptomatic.

ANKLE STABILITY AND JOINT SURFACE INJURY

A Key ligament groups

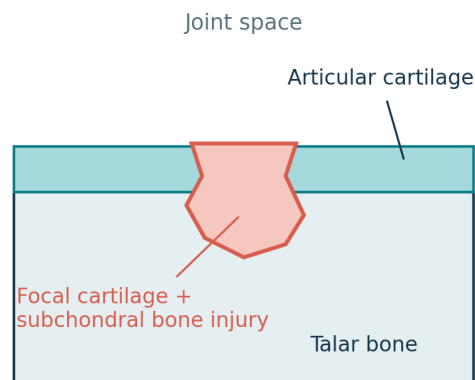
Oblique lateral schematic • anterior right



Selected structures only

B Osteochondral lesion

Conceptual section through the talar dome



Depth and stability vary between lesions.
Not every lesion has an open surface defect.

ATFL: anterior talofibular ligament • CFL: calcaneofibular ligament • AITFL: anterior inferior tibiofibular ligament
Original educational schematics • not to scale • not a diagnostic image or a complete anatomy map

Figure 7.2. Selected lateral ankle ligaments and the distal syndesmosis are distinct from the articular cartilage and subchondral bone involved in an osteochondral lesion. Only the AITFL represents the syndesmotic complex here. [S11, S13, S14, S15]

Osteochondral lesions of the talus

An osteochondral lesion involves articular cartilage and the underlying subchondral bone. It may follow a single ankle injury or present after repetitive loading. Patients may describe deep ankle pain, swelling after activity, catching or an ankle that never recovered after a sprain. Symptoms can be poorly localised. The clinical question is whether the lesion explains the complaint and whether it is stable, repairable and exposed to abnormal joint mechanics. [S14]

Define the whole lesion

Assess the ankle and hindfoot, including stability and alignment. Radiographs may reveal a fragment or subchondral change but can be normal. MRI shows cartilage, marrow and associated soft tissues; CT can clarify the bony architecture, fragment and cyst. MRI marrow oedema can make the apparent bony abnormality seem larger. Record surface area, depth, containment, cysts, fragment viability and previous treatment, rather than using diameter alone. [S14]

Non-operative care

Appropriate stable lesions can be treated initially with activity modification, a period of protection when indicated and rehabilitation that avoids repeatedly provoking joint symptoms. Maintain general conditioning and review pain, swelling and function. Persistent symptoms after approximately three months can justify a surgical discussion, but this is not an automatic deadline for an operation. An acutely displaced fragment, locking or a potentially repairable unstable fragment requires earlier specialist review. [S14]

Selecting an operation

Preserve a sufficiently large viable osteochondral fragment when fixation is feasible. For a small contained lesion without significant bone loss, debridement and bone marrow stimulation may be appropriate. The 2024 DGOU recommendations support this approach for lesions smaller than 1.0 cm² without a bony defect. This is a selection guide, not a universal rule. [S15]

Larger, deep, cystic, uncontained or previously treated lesions require a more individual plan. Options include bone grafting, selected scaffold-assisted repair or osteochondral transplantation. Retrograde drilling may suit selected lesions with an intact cartilage surface. The choice depends on bone and cartilage together, access, prior surgery and local expertise. Correct clinically important instability or malalignment when it threatens the repair. [S15]

Bone marrow stimulation creates repair tissue that should not be described as guaranteed restoration of normal hyaline cartilage. Biological adjuncts also require evidence specific to the indication. Discuss uncertain durability, residual symptoms, stiffness, donor-site morbidity where graft is taken, and the possibility of further surgery. Recovery restrictions differ substantially between procedures. [S15]

Cartilage surgery also requires an honest discussion about what is being preserved and what is being replaced. A viable fragment offers native cartilage that may be worth fixing. Marrow stimulation seeks repair tissue; transplantation introduces an osteochondral unit and may create donor-site consequences. Larger reconstructive procedures can require additional access surgery and protection. The choice should follow the lesion and the patient's goals, with recognition that comparative evidence remains incomplete. [S15]

Turf toe

Turf toe is an injury to the plantar capsuloligamentous and sesamoid complex of the first metatarsophalangeal joint. Forced dorsiflexion of the great toe under axial load is a typical mechanism. It can occur on different playing surfaces. The first MTP joint is critical to push-off, so an injury that appears small externally can significantly impair sprinting, jumping and change of direction. [S16]

Assessment and severity

Locate tenderness around the first MTP joint and sesamoids. Assess bruising, swelling, active plantarflexion and stability gently, comparing with the opposite foot. Obtain suitable radiographs when indicated, including assessment of sesamoid position and possible fracture. Selected comparison views or MRI help when substantial disruption is suspected. A normal initial radiograph does not exclude a significant soft-tissue injury. [S16, S23]

Table 7.2. Turf-toe grades describe severity; examination determines management. [S16]

Grade	Structural pattern	Usual treatment direction
I	Sprain with limited disruption	Protect from hyperextension; progress as symptoms settle
II	Partial disruption	More protection; staged mobility, strength and push-off
III	Complete disruption with potential instability	Specialist assessment; selected repair for instability or associated damage

Protect push-off while restoring function

Avoid repeatedly forcing the injured joint into dorsiflexion. A stiff sole, suitable plate or orthosis and carefully applied taping can reduce painful extension. More substantial injuries may need a boot and a period of restricted loading. As symptoms and stability permit, restore motion within the prescribed range, intrinsic and extrinsic toe strength and gradually increasing push-off demands. Protection should facilitate healing without allowing unnecessary whole-limb deconditioning. [S23]

Surgery is considered for significant instability, displaced or retracted sesamoid structures, traumatic deformity, relevant loose bodies or persistent functional limitation despite appropriate care. Grade III injury does not mean that an identical operation is required in every patient. The decision depends on the structure disrupted, mechanical findings and the patient's functional demands. [S16]

Return to sport

Walking comfortably is an early milestone. Running and cutting require tolerable repeated forefoot loading, sufficient functional hallux motion, stable push-off and confidence. Begin with controlled drills before acceleration, jumping and reactive tasks. Persistent pain on push-off or increasing swelling after training signals that the current demand may exceed capacity. Explain that severe injuries can remain symptomatic for months and may lead to stiffness or degenerative change; a fixed date should not substitute for reassessment. [S23]

Lesser toe plantar plate injury

The lesser-MTP plantar plate is a fibrocartilaginous restraint to dorsal translation of the proximal phalanx. The second MTP joint is commonly affected. Unlike classic acute hallux turf toe, lesser-toe disease often develops through repetitive overload with progressive instability. Hallux valgus, forefoot loading and toe deformity may contribute, but the pattern must be assessed individually. [S17, S18]

Patients describe plantar forefoot pain, swelling or a sense of walking on a small object. Examine toe purchase, widening between toes and progressive deviation. In the vertical drawer test, stabilise the metatarsal head and assess translation of the proximal phalanx. This is different from merely dorsiflexing the toe. Weight-bearing radiographs show alignment; targeted ultrasound or MRI can clarify suspected plate injury. [S17, S18]

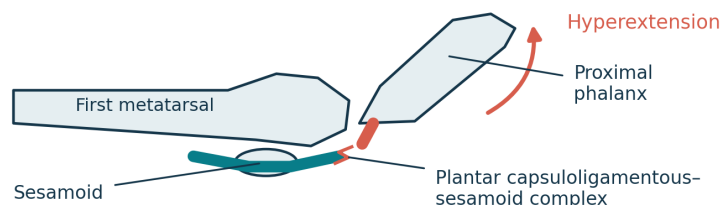
Initial care can include activity adjustment, a stiff-soled shoe, offloading with a correctly positioned metatarsal pad and taping that supports the toe's position. Reduce repeated provocative loading and review the response. Painful instability should not be repeatedly injected without reconsidering the structural diagnosis. [S18]

Persistent pain, progressive deformity or functionally important instability may warrant plantar plate repair or reconstruction with correction of contributing metatarsal or toe deformity. A shortening osteotomy is a selected component, not a substitute for understanding the instability. Discuss stiffness, recurrent deformity, floating toe, transfer pain and the postoperative protection required. [S18]

PLANTAR SUPPORT OF THE MTP JOINT

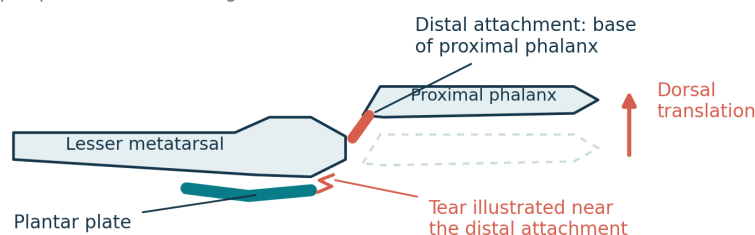
A Turf toe: first MTP hyperextension

Sagittal concept • proximal left, distal right



B Lesser MTP: plantar plate failure

Sagittal concept • proximal left, distal right



MTP: metatarsophalangeal • selected stabilising structures shown; other tendons and ligaments omitted
Original educational schematics • not to scale • examples illustrate mechanism, not a formal injury grade

Figure 7.3. Hallux turf toe involves the first-MTP plantar capsuloligamentous and sesamoid complex. Lesser-MTP plantar plate failure may permit dorsal translation of the proximal phalanx. One sesamoid is shown in sagittal projection; dashed outline indicates the undisplaced phalanx. [S16, S17, S18]

Treatment selection and biological therapies

The sequence of treatment should follow the diagnosis. Establish the pain generator, protect a structure that cannot safely tolerate load, and develop a progressive rehabilitation programme. If recovery stalls, reassess the diagnosis, mechanical factors and treatment delivery before adding another intervention. The following distinctions are particularly relevant to sports practice.

Exercise and shockwave treatment

My interest in shockwave treatment for Achilles and plantar heel pain begins with a practical question: what does it add to good rehabilitation? An adjunctive treatment should be judged against an adequate programme of care. For Achilles tendinopathy, allow a structured course of education, load management and calf strengthening, generally at least twelve weeks. Elective surgery is usually considered only after a substantially longer period, commonly six months or more of active treatment without sufficient improvement. [S2]

Shockwave protocols and study populations differ. Explain the uncertainty for the actual diagnosis and avoid presenting insertional and midportion Achilles disease as one entity. A recent insertional trial found no added benefit over sham when both groups received exercise and education. For plantar fasciitis in the UK, follow the relevant NICE governance and consent arrangements. [S5, S10]

Injection decisions

A large randomised trial found that a single intratendinous PRP injection did not improve chronic midportion Achilles dysfunction compared with sham at six months. This finding argues against routine promises of benefit for that indication. It should not be extrapolated as proof about every PRP preparation or every other condition, but neither should uncertainty be converted into a claim of regeneration. [S4]

Corticosteroid injection into or around the Achilles tendon should be avoided in accordance with NICE CKS advice. At the plantar fascia, any potential short-term pain reduction must be weighed against local complications and the patient's longer-term loading plan. An injection that temporarily reduces pain does not establish readiness for unrestricted sport. [S7, S19, S22]

Bone marrow aspirate concentrate, cell products and other biological adjuncts require indication-specific discussion of evidence, regulation, cost and uncertainty. They do not correct mechanical instability, displace a sesamoid back into position or remove an impinging prominence. For osteochondral surgery, the mechanical environment and the condition of subchondral bone remain central. [S15]

Shared decisions

Document the patient's priorities, reasonable alternatives, anticipated recovery, material risks and the possibility of no improvement. The decision to operate should be linked to a defined problem that the operation can plausibly correct. Arrange physiotherapy, footwear and occupational support early enough to make the proposed recovery realistic.

A patient may reasonably prefer a longer course of rehabilitation to an operation, particularly when symptoms are improving and the structure is stable. Another may accept surgical risk when a defined unstable or impinging lesion prevents essential activity despite appropriate care. I aim to make the reasoning visible: what structure is responsible, what treatment can change, what it cannot change, and what the patient will need to do during recovery.

Rehabilitation and return to sport

Rehabilitation is a progression of exposure. Early work restores comfortable everyday movement within the protection required by the injury or operation. Strength and endurance then support repeated loading; later stages introduce speed, impact and reactive tasks. Progress one meaningful demand at a time and observe the response during the session and afterwards. A flare is information for adjusting the programme, not automatically evidence of a new tear.

For acute lateral ankle sprain, the PAASS consensus provides five useful assessment domains. It is a framework rather than a validated numerical pass score, and it should not be imposed unchanged on cartilage repair, Achilles reconstruction or plantar plate repair. Procedure-specific restrictions still apply. [S12]

Table 7.3. PAASS domains for acute lateral ankle sprain. Adapted in summary from Smith et al. [S12]

Domain	What to assess
Pain	Symptoms during sport and over the preceding 24 hours
Ankle impairments	Range of movement, strength, endurance and power
Athlete perception	Confidence, perceived stability and psychological readiness
Sensorimotor control	Balance and proprioceptive control
Sport performance	Hopping, agility, sport-specific tasks and a full training session

Practical progression

Move from daily function to controlled exercise, then to running or equivalent sport exposure, planned changes of direction, reactive drills and full training. Assess calf endurance, foot control and repeated rather than isolated performance. Compare with pre-injury ability where available, as well as the other side; both limbs may be deconditioned. Numerical symmetry alone can conceal inadequate absolute strength.

Include the athlete's confidence and circumstances. A professional player may have daily rehabilitation support, while a recreational runner may also stand at work and have little recovery time. Coordinate restrictions with the physiotherapist and, with the patient's agreement, the coaching team. Document remaining deficits and the agreed progression. Return to participation, return to the sport and return to previous performance are separate milestones.

I ask patients to describe the day after a training increase as carefully as the session itself. Recurrent swelling, a new limp, progressively worsening morning symptoms or loss of confidence may indicate that the progression was too rapid or that the diagnosis needs review. Good rehabilitation is neither endless caution nor a race through milestones. It is a planned sequence of demands that the recovering tissues and the whole person can meet.

Three clinical lessons

A runner with heel insertion pain that worsens during deep heel drops needs the loading range reviewed before exercise is abandoned. A footballer with recurrent swelling and deep joint pain after a sprain needs assessment for associated intra-articular injury. A patient with painful second-toe drift needs an instability examination, not a diagnosis of “metatarsalgia” alone.

The principle throughout this chapter is to connect symptoms to structure and structure to function. Restore the mechanics that permit recovery, strengthen the capacity to tolerate sport, and use surgery when a defined structural problem warrants it. A durable result is demonstrated in the patient's life and activity.

References for Chapter 7

- [S1]** Chimenti RL, Neville C, Houck J, et al. Achilles Pain, Stiffness, and Muscle Power Deficits: Midportion Achilles Tendinopathy Revision 2024. *J Orthop Sports Phys Ther.* 2024;54(12):CPG1-CPG32. [Read source](#)
- [S2]** de Vos RJ, van der Vlist AC, Zwerver J, et al. Dutch multidisciplinary guideline on Achilles tendinopathy. *Br J Sports Med.* 2021;55:1125-1134. [Read source](#)
- [S3]** Pringels L, Capelleman R, Van den Abeele A, et al. Effectiveness of reducing tendon compression in the rehabilitation of insertional Achilles tendinopathy: a randomised clinical trial. *Br J Sports Med.* 2025;59:640-650. [Read source](#)
- [S4]** Kearney RS, Ji C, Warwick J, et al. Effect of Platelet-Rich Plasma Injection vs Sham Injection on Tendon Dysfunction in Patients With Chronic Midportion Achilles Tendinopathy. *JAMA.* 2021;326:137-144. [Read source](#)
- [S5]** Alsulaimani B, Perraton L, Vallance P, Powers T, Malliaras P. Does shockwave therapy lead to better pain and function than sham over 12 weeks in people with insertional Achilles tendinopathy? A randomised controlled trial. *Clin Rehabil.* 2025;39:174-186. [Read source](#)
- [S6]** Koc TA Jr, Bise CG, Neville C, et al. Heel Pain - Plantar Fasciitis: Revision 2023. *J Orthop Sports Phys Ther.* 2023;53(12):CPG1-CPG39. [Read source](#)
- [S7]** McMillan AM, Landorf KB, Gilheany MF, et al. Ultrasound guided corticosteroid injection for plantar fasciitis: randomised controlled trial. *BMJ.* 2012;344:e3260. [Read source](#)
- [S8]** van Dijk PA, Miller D, Calder J, et al. The ESSKA-AFAS international consensus statement on peroneal tendon pathologies. *Knee Surg Sports Traumatol Arthrosc.* 2018;26:3096-3107. [Read source](#)
- [S9]** American Academy of Orthopaedic Surgeons. Achilles Tendinitis. *OrthoInfo.* Accessed 14 October 2026. [Read source](#)
- [S10]** NICE. Extracorporeal shockwave therapy for refractory plantar fasciitis. HealthTech guidance HTG200, formerly IPG311. Accessed 14 October 2026. [Read source](#)
- [S11]** Martin RL, Davenport TE, Fraser JJ, et al. Ankle Stability and Movement Coordination Impairments: Lateral Ankle Ligament Sprains Revision 2021. *J Orthop Sports Phys Ther.* 2021;51(4):CPG1-CPG80. [Read source](#)
- [S12]** Smith MD, Vicenzino B, Bahr R, et al. Return to sport decisions after an acute lateral ankle sprain injury: introducing the PAASS framework. *Br J Sports Med.* 2021;55:1270-1276. [Read source](#)
- [S13]** van Dijk CN, Longo UG, Loppini M, et al. Conservative and surgical management of acute isolated syndesmotic injuries: ESSKA-AFAS consensus and guidelines. *Knee Surg Sports Traumatol Arthrosc.* 2016;24:1217-1227. [Read source](#)
- [S14]** Walther M, Gottschalk O, Madry H, et al. Etiology, Classification, Diagnostics, and Conservative Management of Osteochondral Lesions of the Talus. 2023 DGOU recommendations. *Cartilage.* 2023;14:292-304. [Read source](#)
- [S15]** Walther M, Gottschalk O, Aurich M. Operative management of osteochondral lesions of the talus: 2024 DGOU recommendations. *EFORT Open Rev.* 2024;9:217-234. [Read source](#)
- [S16]** British Orthopaedic Foot & Ankle Society. Turf Toe Injury. *Hyperbook.* Accessed 14 October 2026. [Read source](#)
- [S17]** Nery C, Coughlin MJ, Baumfeld D, et al. Classification of metatarsophalangeal joint plantar plate injuries: history and physical examination variables. *J Surg Orthop Adv.* 2014;23:214-223. [Read source](#)
- [S18]** British Orthopaedic Foot & Ankle Society. Lesser Toe Instability. *Hyperbook.* Accessed 14 October 2026. [Read source](#)
- [S19]** American Academy of Orthopaedic Surgeons. Plantar Fasciitis and Bone Spurs. *OrthoInfo.* Accessed 14 October 2026. [Read source](#)
- [S20]** British Orthopaedic Foot & Ankle Society. Ankle Instability. *Hyperbook.* Accessed 14 October 2026. [Read source](#)
- [S21]** British Orthopaedic Foot & Ankle Society. Deltoid Ligament Injury. *Hyperbook.* Accessed 14 October 2026. [Read source](#)
- [S22]** NICE Clinical Knowledge Summaries. Achilles tendinopathy: Management. Accessed 14 October 2026. [Read source](#)
- [S23]** Faltus J, Mullenix K, Moorman CT III, Beatty K, Easley ME. Case Series of First Metatarsophalangeal Joint Injuries in Division 1 College Athletes. *Sports Health.* 2014;6:519-526. [Read source](#)

[S24] British Orthopaedic Foot & Ankle Society. Achilles tendon acute rupture. BOFAS Hyperbook. Accessed 14 October 2026. [Read source](#)

[S25] Myhrvold SB, Brouwer EF, Andresen TKM, et al. Nonoperative or Surgical Treatment of Acute Achilles' Tendon Rupture. *N Engl J Med*. 2022;386:1409-1420. doi:10.1056/NEJMoa2108447. [Read source](#)

[S26] Costa ML, Achten J, Marian IR, et al. Plaster cast versus functional brace for non-surgical treatment of Achilles tendon rupture (UKSTAR): a multicentre randomised controlled trial and economic evaluation. *Lancet*. 2020;395:441-448. doi:10.1016/S0140-6736(19)32942-3. [Read source](#)

[S27] British Orthopaedic Foot & Ankle Society. Chronic Achilles tendon rupture. BOFAS Hyperbook. Accessed 14 October 2026. [Read source](#)

[S28] NICE. Venous thromboembolism in over 16s: reducing the risk of hospital-acquired deep vein thrombosis or pulmonary embolism. NG89. Lower limb immobilisation. [Read source](#)

[S29] Saxena A, Giai Via A, Grävare Silbernagel K, et al. Current Consensus for Rehabilitation Protocols of the Surgically Repaired Acute Mid-Substance Achilles Rupture: A Systematic Review and Recommendations From the GAIT Study Group. *J Foot Ankle Surg*. 2022;61:855-861. doi:10.1053/j.jfas.2021.12.008. [Read source](#)

CHAPTER 08

08 Foot and Ankle Trauma

The philosophy of treating the injured foot

Foot and ankle trauma must be understood through the energy that entered the limb, the direction in which it travelled, and the tissues that absorbed it. The radiograph shows the fracture; it does not show the full biological injury. A technically satisfactory reconstruction can still fail when the soft tissues, blood supply, ligamentous stability or rehabilitation needs have been underestimated.

In my practice, the starting point is to understand the patient and the mechanism before selecting an implant. A pilon fracture can reasonably be regarded as a severe soft tissue injury containing a fractured bone. A rotational ankle fracture can be understood as disruption of a ligamentous ring, sometimes through its bony attachments. A crushed calcaneus changes the shape and lever arm of the hindfoot. An unstable Lisfranc injury disrupts the relationship between the columns of the foot and compromises the platform for push-off. These descriptions help explain why reduction, fixation and aftercare differ between apparently similar fractures.

This chapter addresses adult tibial and long-bone trauma together with pilon, ankle, talar, calcaneal, navicular, Lisfranc, metatarsal and toe injuries. It connects classification to the decisions that matter: immediate reduction, protection of the soft tissues, restoration of joint congruity, recovery of length and alignment, and appropriate progression towards weight bearing. Operative preferences described in the first person represent my practice. Their application depends on the individual injury, available expertise and the patient's circumstances.

Initial assessment and protection of the limb

High energy foot and ankle trauma may accompany injuries to the head, chest, abdomen, pelvis, spine and other limbs. Assessment therefore begins with structured major trauma resuscitation using ATLS principles, followed by a complete secondary survey. A dramatic ankle deformity must not distract from life-threatening injury. Falls from height should prompt examination of the opposite heel, the remainder of both lower limbs and the spine as clinically indicated.

The limb assessment records skin condition, wounds, deformity, swelling, blisters, perfusion, pulses, sensation and motor function. Findings should be documented before and after reduction or splintage. A threatened skin envelope, an irreducible dislocation, deteriorating perfusion or suspected compartment syndrome demands urgent senior assessment. Imaging must not delay reduction when the deformity threatens skin or circulation. Palpable pulses do not exclude compartment syndrome.

Open injuries require prompt intravenous antibiotics according to the trauma network protocol, ideally within one hour of injury, and assessment of tetanus protection. The wound is documented and covered with a saline-moistened dressing and an occlusive layer. Repeated wound probing or emergency department washouts are avoided.

Definitive wound excision, fixation and coverage are coordinated with the appropriate surgical team. Open hindfoot and midfoot injuries should enter an orthoplastic pathway; vascular expertise is added when perfusion is threatened. [T1]

Analgesia, elevation, suitable splintage and repeat examination continue while the treatment plan develops. Swelling is dynamic: skin that appears acceptable initially may deteriorate over the following hours. Thromboembolism risk assessment, smoking cessation support, glycaemic control, nutrition and practical arrangements for restricted weight bearing belong to the early plan. Baseline mobility, neuropathy, peripheral vascular disease, frailty and the patient's ability to use walking aids may change the safest treatment.

Table 8.1 Clinical priorities before definitive reconstruction

Finding	Why it matters	Immediate priority
Open wound communicating with fracture	Contamination and soft tissue loss	Antibiotics and coordinated operative wound care
Deformity with skin blanching or tenting	Pressure can cause skin necrosis	Prompt reduction and repeat skin assessment
Reduced perfusion or new neurological deficit	Possible vascular injury or nerve compromise	Urgent reduction and specialist reassessment
Increasing pain with tense swelling	Possible compartment syndrome	Urgent clinical assessment and treatment pathway
Severe swelling or fracture blisters	Higher wound risk from premature exposure	Stabilise and reassess the soft tissue envelope
Plantar midfoot bruising or unexplained midfoot pain	Possible occult Lisfranc injury	Protect weight bearing and obtain appropriate imaging

Arterial injury and the threatened limb

A vascular emergency changes the sequence of care. Ongoing major haemorrhage requires immediate control and resuscitation. A pulseless deformed limb is urgently realigned and splinted, then circulation is reassessed and documented. Persistent asymmetry of pulses or other evidence of impaired perfusion warrants consultant assessment and rapid vascular investigation. CT angiography assists diagnosis when appropriate, but the pathway must lead promptly to reperfusion. [T30]

The June 2026 BOASt treats traumatic arterial injury as an emergency without a safe period of ischaemia and recommends that revascularisation commence within one hour of hospital arrival. A temporary shunt can restore flow while skeletal stabilisation and definitive repair are coordinated. This requires orthopaedic and vascular or plastic

surgical expertise, with fasciotomy considered after reperfusion. A nominal time target is not permission to wait. [T30]

For the foot and ankle surgeon, the practical lesson is to recognise when the limb needs a team rather than another radiograph. The record should communicate what changed, when it changed and who is taking responsibility. A handover that merely says the foot is neurovascularly intact is less useful than a timed account of pulses, perfusion, motor and sensory findings before and after each intervention.

Compartment syndrome and repeated examination

Compartment syndrome is an evolving clinical emergency. Escalating pain, pain with passive muscle stretch and tense swelling should prompt urgent reassessment; a palpable pulse does not reassure against it. The July 2025 BOAST recommends hourly documented assessment for patients at risk. When examination is unreliable or findings are inconclusive, pressure measurement and senior review assist decisions. A diastolic-minus-compartment pressure below 30 mmHg identifies increased risk, rather than a self-sufficient diagnostic rule. [T31]

A diagnosis of acute compartment syndrome requires immediate decompression. The involved compartments must be identified; the standard two-incision, four-compartment release for the leg should not be confused with a procedure for the foot. The BOAST acknowledges lack of consensus for foot compartment syndrome and requires a documented rationale for management. Patients with late presentation also need senior individual assessment because decompression of extensively necrotic muscle has different risks. [T31]

Analgesia and regional anaesthesia need a shared monitoring plan. A comfortable patient cannot automatically be assumed to have safe compartments, particularly if sedation, neuropathy or a nerve block limits examination. Nursing observations, changes in analgesic requirement and clear escalation arrangements are integral to the surgical pathway. [T31]

Open injury as a combined reconstructive problem

The decision about fixation and the decision about coverage belong to one plan. Debridement removes contamination and nonviable tissue while preserving structures that can contribute to reconstruction. For open long-bone, hindfoot and midfoot injuries, orthopaedic and plastic surgeons should plan together. The BOAST advises immediate debridement for highly contaminated wounds or vascular compromise, within 12 hours for other solitary high-energy injuries, and within 24 hours for other low-energy injuries. These are maximum pathway targets, interpreted with the patient's condition. [T1]

Definitive cover should accompany definitive internal fixation; when cover is not achieved at the first debridement, the standard target is within 72 hours of injury. A temporary dressing does not complete reconstruction. The patient also needs information about likely operations, expected function and rehabilitation. Limb salvage or amputation decisions require multidisciplinary assessment and discussion with the patient and family, rather than reliance on an injury score alone. [T1]

Tibial and long bone fractures in the injured limb

The foot cannot be understood separately from the tibia that delivers load to it. A tibial fracture may be isolated, extend into the knee or ankle, or accompany a second fracture elsewhere in the limb. The assessment therefore follows the entire bone and both neighbouring joints. Examination of the foot should be repeated after the obvious long-bone injury has been stabilised, because swelling, distraction and inability to bear weight can conceal associated midfoot or hindfoot trauma. [T39]

High-energy shaft fractures combine a mechanical failure with injury to muscle, periosteum, skin and blood supply. A small wound can communicate with a substantial zone of damage. Conversely, a closed fracture can still have extensive internal soft tissue injury. The terms open and closed identify an important distinction in contamination, but they do not describe the whole biological problem. Open injury and compartment syndrome follow the emergency pathways already described.

Fracture configuration helps explain the force: a spiral pattern suggests a rotational component, while transverse, wedge and segmental configurations may reflect other combinations of bending, compression and direct impact. The image does not reconstruct the event with certainty. I use mechanism to guide the search for associated injury, then base treatment on the observed fracture, physiology, tissue condition and functional needs.

Length alignment rotation and biological preservation

A healed tibia can leave a poorly functioning foot if its length, rotation or coronal and sagittal alignment are wrong. These features must be checked during treatment rather than inferred from one acceptable radiographic projection. Rotational assessment requires particular care: apparently satisfactory AP and lateral films can coexist with a clinically important difference in foot progression. The opposite limb is a useful reference when it is uninjured, while recognising that individuals may have pre-existing asymmetry.

In a multifragmentary shaft fracture, the surgeon does not necessarily need to expose and anatomically rebuild every intermediate fragment. Indirect restoration of the main segments can protect the attachments through which small fragments retain their blood supply. Bridge plating uses the implant as a splint across the fracture zone, with fixation in the principal segments. Its success depends on planned mechanics and preserved biology, not merely the presence of a long plate. [T32]

An articular extension changes the problem. Joint congruity needs its own reduction and fixation strategy, while the metaphysis or shaft may be managed through a different stability principle. This distinction explains why a tibial nail or bridge plate cannot by itself be assumed to have reconstructed an associated ankle joint injury. The operative plan should identify each component and the order in which it will be addressed.

Choosing a fixation strategy

Intramedullary nailing is an important option for many adult tibial shaft fractures. The nail lies within the medullary canal and locking screws control length and rotation. Fractures near either end of the bone require particular attention because a short segment within a wider canal is harder to control. Entry point, reduction, imaging and supplementary reduction methods matter. The choice between infrapatellar and semi-extended suprapatellar techniques depends on the injury, equipment and experience; neither should substitute for careful restoration of alignment. [T33]

A plate may be preferred for selected patterns, especially where fragment capture, an associated articular injury or anatomy makes nailing unsuitable. The skin and subcutaneous position of the tibia impose limits on exposure and implant placement. A minimally invasive approach can preserve the fracture environment, but small incisions do not guarantee a good reduction. The implant, working length, screw distribution and quality of bone must form a coherent construct. [T32]

In a technical note with Kougioumtzis and Chloros, we described plate-assisted intramedullary nailing of distal tibial fractures. A reduction plate can help maintain the distal fragment relationship while the nail is inserted. This is an example of using two techniques to solve a reduction problem, rather than treating plate and nail as mutually exclusive choices. The report demonstrates a technique; it is not a comparative trial proving that a combined construct is necessary or superior in every distal tibial fracture. [T36]

External fixation can be temporary damage control or part of definitive treatment. Circular fixation is particularly relevant to selected complex injuries, bone loss, deformity and situations in which the soft tissue environment limits internal implants. Pins and wires require appropriate placement, care and surveillance. The patient must understand the practical burden of frame treatment, including follow-up and rehabilitation. The AO principles emphasise stabilisation that is appropriate to the pattern and tissue condition rather than allegiance to one implant. [T34]

Selected closed, stable and acceptably aligned fractures may be treated with casting or bracing and close review. The decision requires confidence that alignment can be maintained and that the patient can manage the treatment. Loss of position, pressure problems or failure to progress should trigger reassessment. Nonoperative care is an active treatment pathway with repeated decisions, rather than the absence of a surgical decision.

Whole patient timing and recovery after long bone injury

In the multiply injured patient, the timing and extent of surgery depend on the physiological response to trauma and resuscitation. Early definitive stabilisation can help pain control, nursing and mobilisation when the patient can tolerate it. Temporary stabilisation may be more appropriate when physiology, contamination or soft tissue compromise makes a long reconstruction unsafe. The labels early total care, early appropriate care and damage control describe strategies whose usefulness depends on repeated clinical assessment. They are not interchangeable timetables. [T34]

Tibial recovery needs surveillance of union, alignment, the wound and the function of the ankle and knee. Pain or loss of movement at either joint can limit walking even when the shaft unites. Calf weakness, equinus, altered sensation and deconditioning deserve early attention within the restrictions of the reconstruction. The permitted load must reflect all injuries in the limb: an implant that allows loading of a tibial shaft fracture does not override restrictions required for a concomitant talar or Lisfranc reconstruction.

Persistent failure to heal is approached by asking about both stability and biology. Infection, an unhelpful mechanical environment, bone loss, impaired circulation and host factors may coexist. A repeat operation that only adds an implant can fail if the underlying problem has not been identified. Revision planning may require infection specialists, plastic surgeons, vascular assessment and limb reconstruction expertise. The aim is a united, aligned, usable limb, not a radiograph that merely contains more metalwork.

Pilon fractures

Mechanism and biological injury

A pilon fracture involves the distal tibial weight-bearing surface, or plafond. The talus acts as an impacting structure when an axial load is transmitted through the ankle. Foot position, loading direction, rotational forces and bone quality determine which part of the plafond fails and whether the injury produces a split, impaction, comminution or a combination of these features. High energy injuries frequently extend into the metaphysis and may be associated with a fibular fracture. [T40]

The same event injures the skin, subcutaneous tissues, muscles and microcirculation. My description of the tissues as almost being cooked conveys the severity of this insult, but the process is mechanical disruption and vascular injury rather than a thermal burn. Swelling, haemorrhage and evolving tissue necrosis explain why immediate extensive exposure may be unsafe. The visible fracture is only one part of the injury.

Not every pilon fracture follows a high energy mechanism. Lower energy partial articular injuries also occur, particularly where bone quality is poor. The treatment must follow the actual morphology and tissue condition rather than the diagnostic label alone. AO/OTA distinguishes partial articular distal tibial fractures, in which some joint surface remains connected to the shaft, from complete articular fractures, in which the entire articular component is separated from it. [T3, T4]

Span scan and plan

For a displaced high energy fracture with a compromised soft tissue envelope, the familiar sequence is span, scan and plan. Temporary ankle-spanning external fixation restores approximate length and alignment, reduces deforming pressure and protects the tissues. Pin sites are selected with the definitive incisions, implants and potential flap reconstruction in mind. Excessive distraction and avoidable injury to future operative corridors should be prevented.

CT after provisional reduction clarifies the position of the major fragments, central impaction, posterior involvement and metaphyseal defects. It allows the surgeon to

decide which fragment will serve as a reference and which approach gives useful access to the articular injury. A scan of a grossly displaced fracture may be less useful for planning than one obtained after alignment has been improved. [T3]

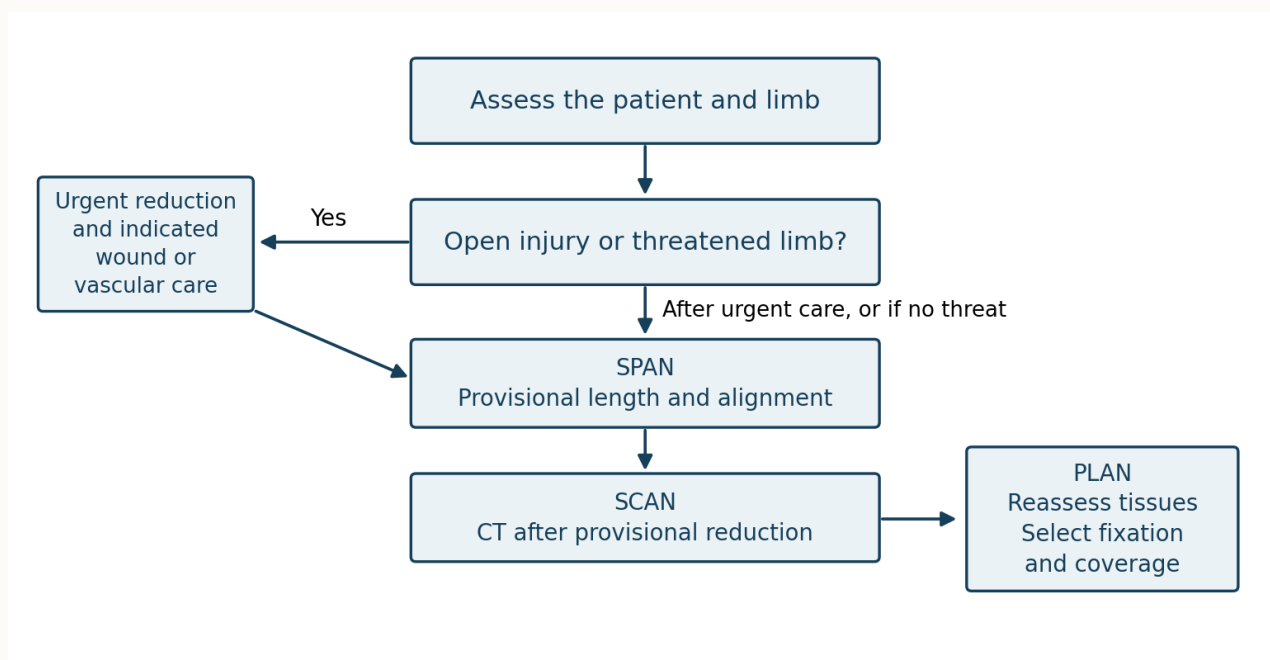


Figure 8.1 Decision sequence for a displaced high energy pilon fracture. Urgent limb-threatening problems are treated immediately; definitive fixation is selected after reassessment of physiology, imaging and soft tissues. This is a conceptual pathway, not a fixed timetable.

Definitive reconstruction

The operative objectives are restoration of the tibial articular surface, appropriate support of depressed segments, recovery of length and coronal and sagittal alignment, and a construct compatible with soft tissue healing. Options include open reduction and internal fixation with plates and screws, limited internal fixation combined with a circular frame, or other limb reconstruction strategies. Severe cartilage destruction may occasionally justify primary arthrodesis after specialist discussion. No single construct suits every pilon fracture.

Fibular fixation may help restore length and assist reduction, but its timing and necessity depend on the tibial pattern and the eventual reconstruction. A malreduced fibula can obstruct the tibial reduction. The choice of anterolateral, anteromedial or posterior access follows the fracture map and the available skin envelope. A staged approach is common, but the decision to proceed is based on tissue recovery rather than a predetermined number of days. [T3, T25]

Patients should understand that even an anatomically reconstructed plafond may develop post-traumatic arthritis because cartilage damage occurred at the moment of injury. Wound problems, infection, stiffness, delayed union, nonunion and malalignment must be considered during consent and follow-up. The quality of reconstruction matters, but it cannot reverse all of the initial biological damage.

Ankle fractures

A ring of bone and ligament

The ankle mortise depends on the relationship between the tibia, fibula and talus, together with the deltoid ligament and syndesmotic complex. My description of ankle fractures as ligamentous injuries with bony attachments is useful for rotational patterns: failure can pass through a ligament, its attachment or the adjacent malleolus. It should not be taken to mean that all ankle fractures are purely ligamentous. Impaction, shear and partial articular patterns need separate attention. [T43]

Assessment includes anteroposterior, mortise and lateral radiographs, with imaging of the proximal fibula when the examination suggests a Maisonneuve injury. CT is particularly useful for complex posterior malleolar injuries, articular impaction, atypical displacement and operative planning. The whole mortise is assessed, including talar shift and tilt, fibular length and rotation, and medial and syndesmotic stability. [T2]

Weber and Lauge Hansen classifications

Weber describes the level of the fibular fracture relative to the syndesmosis. It provides a concise anatomical description, but the fibular level alone does not establish whether the ankle is stable. A Weber B injury, for example, may be stable or may accompany substantial medial and posterior disruption.

Table 8.2 Weber classification

Type	Fibular fracture level	Additional assessment
A	Below the syndesmosis	Medial injury, talar alignment and associated impaction
B	At the level of the syndesmosis	Deltoid or medial malleolar injury, posterior injury and functional stability
C	Above the syndesmosis	Syndesmotic disruption, proximal fibular extension and medial injury

Lauge-Hansen links foot position to the deforming force. Its four principal patterns provide a useful way to anticipate associated injury, although real trauma does not always follow the experimental sequence. The first term describes the position of the foot; the second describes the direction of the applied force or talar movement relative to the leg. [T24]

Table 8.3 Principal Lauge Hansen patterns

Pattern	Typical structures or morphology to examine
Supination external rotation	Anterior syndesmotic injury, oblique fibular fracture, posterior injury and possible medial failure
Pronation external rotation	Medial failure, syndesmotic disruption and a higher fibular fracture with possible posterior injury
Supination adduction	Lateral avulsion or ligament failure, vertical medial malleolar fracture and medial plafond impaction
Pronation abduction	Medial failure and syndesmotic injury with a transverse or comminuted fibular fracture

Atypical ankle fractures and the six pattern framework

Some injuries show anterior or posterior talar translation, marginal plafond failure or impaction that is poorly explained by the usual rotational categories. Joumah and Bakhshayesh described such injuries in a BOFAS conference abstract. The abstract identifies four combined mechanisms involving hyperflexion or hyperextension with pronation or supination. It supports attention to atypical morphology; it does not by itself validate a universal classification or an automatic requirement for syndesmotic fixation. [T5, T6]

For the broader framework presented in this chapter, I include two pure sagittal patterns as well as the four combined patterns. This produces six categories. To avoid ambiguity, hyperflexion here means excessive plantarflexion and hyperextension means excessive dorsiflexion. Pronation and supination describe the accompanying composite foot position; they are not simple substitutes for isolated ankle eversion and inversion.

Table 8.4 Bakhshayesh six pattern descriptive framework

Sagittal component	Pure pattern	With pronation	With supination
Hyperflexion or excessive plantarflexion	Pure hyperflexion	Hyperflexion pronation	Hyperflexion supination
Hyperextension or excessive dorsiflexion	Pure hyperextension	Hyperextension pronation	Hyperextension supination

The purpose is to make the surgeon ask where compression, tension and shear occurred. For each category, CT should establish the actual impaction, rim fragments, talar translation and syndesmotic relationships. The proposed mechanism should not be used to invent an unobserved fracture line. The six-pattern system is presented as an author-proposed descriptive framework requiring reliability and outcome validation.

Some of these injuries overlap morphologically with partial articular pilon fractures. However, partial articular is an anatomical description, not a synonym for every atypical ankle fracture. The distinction depends on how much articular surface remains continuous with the tibial shaft and on the actual fracture configuration. [T4]

Treatment according to stability and morphology

A stable fracture with a congruent mortise may be treated without surgery, with appropriate support and follow-up. Where stability is uncertain, reassessment and weight-bearing radiographs, when tolerable and appropriate, can clarify the position. An unstable mortise generally requires reduction and a method of maintaining it; surgery is selected in relation to fracture pattern, tissue condition, functional demand and medical risk. [T2, T28]

At operation, restoration of fibular length and rotation, the medial structures and the posterior plafond must be considered together. Posterior malleolar management should account for articular congruity, impaction, incisural involvement and stability. After bony reconstruction, the syndesmosis is assessed and stabilised if unstable. Neither a classification label nor one fragment-size threshold should replace this assessment. Selected frail patients may require an alternative strategy, including close-contact casting or a hindfoot nail, with explicit discussion of the functional trade-offs. [T2]

Fibular intramedullary fixation is another way to stabilise selected lateral malleolar injuries while limiting exposure. Our systematic review with Raufi and colleagues compared fibular nails and plates across nine studies. It supports considering nailing as an alternative within an individual assessment of fracture pattern, bone, soft tissues and reduction requirements. Heterogeneity, study size and follow-up limit a claim of universal superiority. Whatever device is chosen, accurate fibular and syndesmotic relationships remain essential. [T37]

Frailty can shift the balance towards a construct that supports practical mobilisation. In our two-centre retrospective study with Ismayl and colleagues, long hindfoot fixation using standard tibial nails was studied in 36 patients older than 60 with ankle or distal tibial fractures. This was an observational experience in a selected population, including open injuries. It provides evidence of feasibility, but does not establish superiority over plates, fibular nails or casting. A hindfoot nail crosses the ankle and subtalar joints, and the resulting loss of movement must be weighed against the patient's mobility and rehabilitation needs. [T38]

Talar fractures

Neck fractures and the Hawkins classification

The talus transmits load between the leg and foot through several articular surfaces. Talar neck fractures commonly result from high energy loading with forced dorsiflexion, often with a rotational component. Talar body and process fractures may arise through different combinations of axial compression, shear and impingement. Displacement can compromise the blood supply as well as the ankle and subtalar joint relationships.

The Hawkins classification applies to talar neck fractures. Its increasing grades describe progressively greater associated joint displacement and generally increasing risk of osteonecrosis. It should not be applied indiscriminately to talar body or posterior process fractures. [T7]

Table 8.5 Hawkins classification with the later type IV extension

Type	Principal finding
I	Nondisplaced talar neck fracture with maintained joint alignment
II	Displaced neck fracture with subtalar subluxation or dislocation and a reduced ankle joint
III	Neck fracture with subtalar and tibiotalar dislocation
IV	Type III pattern with additional talonavicular dislocation

Urgent reduction is required for a dislocated talus, threatened skin or vascular compromise. Definitive fixation can follow once the limb has been reduced, the soft tissues assessed and CT-based planning completed. Urgency of reduction and timing of definitive fixation are related but distinct decisions. [T8]

Articular reconstruction and preservation of blood supply

CT defines displacement, comminution, joint incongruity and associated osteochondral fragments. A genuinely nondisplaced neck fracture with preserved joint relationships may be treated non-operatively under close surveillance. Displaced neck and body fractures generally require anatomical reconstruction. A residual articular step or gap around 2 mm is clinically important, but a universal rule that surgery begins only above 2 mm is inappropriate: smaller displacement, malrotation, instability or dislocation may also matter.

Combined anteromedial and anterolateral approaches are frequently useful for talar neck reconstruction. They permit assessment of both sides of the neck and help avoid varus or rotational malreduction. The fracture pattern may require different access for body or posterior injuries, occasionally including a malleolar osteotomy. Viable soft tissue attachments are preserved; loose nonviable fragments and interposed tissue are dealt with selectively. Plates and screws are chosen to restore alignment without collapsing a comminuted segment through excessive compression. [T8, T9]

Posterior and lateral process injuries

The tail of the talus is more precisely described as its posterior process. Its medial and lateral tubercles lie around the flexor hallucis longus groove. Posterior process fractures should be distinguished from an os trigonum, and lateral process fractures should be sought when symptoms persist after an apparent ankle sprain. CT is often valuable where plain radiographs do not explain the clinical findings.

A large displaced articular process fragment may need fixation. A small, comminuted or symptomatic ununited fragment may be treated differently, including excision in

selected circumstances. Consequently, dual anterior approaches and screw fixation are not universal solutions for every talar fracture. The injured articular surface and fragment location determine the access and treatment. [T10]

Follow-up assesses union, alignment, avascular necrosis, stiffness and post-traumatic arthritis. The presence of a Hawkins sign is reassuring for vascularity, but its absence alone does not prove osteonecrosis. Weight bearing is advanced according to healing, symptoms, fixation and the condition of the talar body rather than a calendar date alone. [T29]

Calcaneal fractures

Mechanism and restoration of heel shape

An axial load drives the talus into the calcaneus. Fracture propagation and the relative movement of the heel create combinations of posterior facet depression, loss of height, widening, shortening and tuberosity malalignment. Achilles traction influences displacement of the posterior tuberosity, particularly in tongue-type and avulsion patterns. The plantar soft tissues constrain the injury, but calcaneal shortening should not be attributed solely to Achilles and plantar fascia pull. [T41]

The reconstruction must restore the heel as a three-dimensional structure. Posterior facet congruity is essential, but heel width, height, length and tuberosity alignment influence shoe wear, tendon function and gait. Residual varus and a prominent lateral wall can remain disabling despite apparent fracture union.

Böhler's angle on the lateral radiograph commonly decreases with collapse of the posterior facet. Gissane's angle can increase or decrease according to the fracture pattern and projection; it is not invariably reduced. These measurements complement CT and direct assessment rather than independently determine treatment. The uninjured side may help interpret individual anatomy when comparison is appropriate. [T11, T14]

Sanders classification and the fragment map

Sanders classification is based on the posterior facet on coronal CT. It is valuable for describing articular comminution, but it does not fully describe the tuberosity, lateral wall, anterior process or calcaneocuboid joint. Essex-Lopresti's distinction between joint-depression and tongue-type patterns adds a different, useful view of the injury. [T11]

Table 8.6 Sanders classification

Type	Posterior facet pattern
I	Nondisplaced articular fracture regardless of the number of fracture lines
II	Displaced two-part posterior facet fracture
III	Displaced three-part posterior facet fracture
IV	Highly comminuted posterior facet with four or more articular fragments

Within the Sanders scheme, A, B and C identify fracture-line positions across the posterior facet from lateral through central to medial. They should not be used interchangeably as labels for the lateral wall, entire posterior facet and sustentaculum. For operative planning I describe the lateral wall, depressed facet fragment or fragments, sustentacular component and tuberosity separately. The sustentacular fragment is often a useful reference, but its position must be checked rather than assumed to be normal in every injury. [T11, T12]

Posterior skin must be examined carefully in a displaced tongue-type or tuberosity avulsion fracture. Skin tenting or blanching requires urgent reduction and protection; waiting for swelling to settle can allow preventable necrosis. In other cases, the timing and extent of exposure are chosen according to the skin condition and overall injury. [T26]

My modified sinus tarsi approach

My approach aims to address the articular and extra-articular components through a modified sinus tarsi exposure while allowing application of a standard lateral calcaneal plate. The rationale is to obtain fixation of the body and tuberosity as well as the posterior facet, particularly when the fracture extends beyond the region supported by a short sinus tarsi plate. This technique is described in our manuscript with Tania Tanello and Ahmed Yousef. [T13, T14]

The operative plan includes controlled mobilisation of the lateral soft tissue envelope, careful identification and protection of the peroneal tendons and sural nerve, reduction of the depressed articular component and correction of the posterior tuberosity. Temporary wires maintain the reduction while plate position and screw trajectories are checked. Direct articular assessment and multiplanar fluoroscopy are complementary. The exposure must be adequate for reconstruction without unnecessary stripping of viable tissues.

Although the skin incision is limited, the deeper exposure can be substantial. Soft tissue handling therefore remains central to the technique. The implant should support the specific fracture rather than force the fracture into the shape of the plate. Reduction of heel width, tuberosity varus and length is checked alongside the posterior facet and calcaneocuboid joint.

The manuscript describes a technical approach and early clinical experience. Comparative superiority, a lower infection rate or a guarantee of satisfactory function cannot be inferred from a small uncontrolled series. Choice among non-operative care, percutaneous fixation, sinus tarsi exposure, extensile exposure and, in selected unreconstructable injuries, subtalar fusion remains individualised. Implant brand is secondary to fracture capture, reduction, biological preservation and reliable fixation.

Navicular fractures and the medial column

The navicular is a central link in the medial column and the talonavicular articulation. Injury can compromise both column length and the relationship between the hindfoot and forefoot. Examination and CT should therefore look beyond the navicular itself for talonavicular, naviculocuneiform, cuboid and other associated midfoot injuries.

Avulsion and tuberosity injuries differ from navicular body fractures. Sangeorzan's body-fracture classification considers the fracture plane and associated displacement rather than comminution alone. Type I is a coronal fracture without angulation of the forefoot; type II is an oblique fracture, typically dorsolateral to plantar-medial, with medial displacement of the forefoot; type III is a comminuted sagittal body fracture with lateral displacement of the forefoot. CT defines the individual pattern more fully. [T16]

My practical reconstruction sequence follows the amount of surviving structure. A simple displaced articular fracture may permit reduction and screw fixation. Comminution may require a plate that holds the reconstructed navicular without collapsing it. When local fixation cannot maintain medial column length, temporary bridge fixation or an external device can protect the reconstruction. A bridge plate maintains length and alignment; it should not over-distract the joints or be mistaken for a planned fusion. [T15]

Table 8.7 Navicular reconstruction according to morphology

Morphology	Reconstruction objective	Potential method
Stable nondisplaced injury	Preserve alignment while healing	Immobilisation and clinical and imaging follow-up
Simple displaced body fracture	Restore articular congruity and bone shape	Direct reduction with screw fixation
Multifragmentary but reconstructable body	Maintain reconstructed shape and column length	Screws with a supporting navicular plate
Severe comminution or column instability	Protect length while fragments heal	Temporary spanning plate or external fixation with selected internal fixation

Persistent pain may reflect articular damage, malalignment, nonunion or osteonecrosis. Follow-up should assess the medial arch, neighbouring joints and the entire column. Hardware spanning a joint requires an explicit review and removal plan once healing and stability permit. [T15]

Lisfranc injuries

Mechanism and patterns of displacement

Lisfranc injuries involve the tarsometatarsal complex. The recessed base of the second metatarsal and the ligamentous relationship between the medial cuneiform and second metatarsal are especially important to stability. The injury may be a subtle ligament disruption, an obvious fracture-dislocation, or part of a crushed foot.

In my interpretation of many indirect injuries, the midfoot is loaded in plantarflexion, with a varus or supination component at the hindfoot. Tension develops across the plantar structures and the medial tarsometatarsal region. If disruption propagates between the first and second rays, the first ray may displace medially while the remaining rays move laterally. If the force is concentrated around the second metatarsal base, the first ray may remain relatively aligned while the second and adjacent rays displace laterally. Dorsal translation is an important component to look for.

This mechanism is useful for understanding selected divergent and lateral-displacement patterns. It is not the only mechanism: direct crush, abduction, rotation and other loading positions also produce Lisfranc injuries. Dorsal displacement is common but is not obligatory. Reduction must correct the actual three-dimensional deformity, including rotation and plantar displacement where present. The conventional term is tarsometatarsal, or TMT, joint; cuneometatarsal describes the first three articulations more specifically. [T17, T21]

Diagnosis and the threshold for stabilisation

Midfoot swelling, plantar bruising, focal TMT tenderness and difficulty bearing weight should prompt suspicion, even when the initial radiographs appear nearly normal. Standard views include anteroposterior, oblique and lateral images. Weight-bearing comparison views can reveal instability when the patient can safely tolerate them. CT identifies fractures and joint incongruity; MRI may help assess ligament injury when the diagnosis remains uncertain. A displaced injury should not be forced into weight bearing to demonstrate what is already apparent. [T42]

The distinction between a stable injury and an unstable injury is more useful than displacement on a single unloaded image. Selected injuries shown to be stable can recover well with non-operative protection and follow-up. Displaced or unstable injuries require restoration and maintenance of alignment. Treatment aims to reduce the risk of chronic pain, deformity and post-traumatic arthritis, but anatomical fixation cannot guarantee that arthritis will never develop. [T20, T21]

Open reduction and internal fixation and primary arthrodesis both have roles. The choice considers cartilage damage, ligamentous versus bony disruption, reconstructability, chronicity, patient goals and the joints involved. Randomised studies comparing selected strategies do not establish that one method is best for every injury. In particular, results from first-TMT bridge plating combined with fusion of the second and third TMT joints should not be interpreted as evidence for three-joint bridge plating in all patients. [T18, T19]

My single incision reconstruction sequence

I commonly use a longitudinal dorsal incision centred over the second ray. The related modified dorsal approach was published by Philpott, Lawford, Lau, Chambers, Bozin and Oppy at the Royal Melbourne Hospital. It uses tissue windows to reach the involved joints. My description below explains the principles of my operative sequence rather than reproducing every interval of that publication. [T17]

Following skin incision, the extensor apparatus and the extensor hallucis brevis region are identified. Fascial release and controlled mobilisation provide access while the dorsalis pedis artery and deep peroneal nerve are identified and protected. Medial and lateral working windows are developed as required. Retractors, including a Langenbeck where suitable, must not apply sustained focal pressure to the neurovascular bundle. Adequate exposure should be gained through deliberate dissection rather than forceful traction.

I first restore the alignment of the first TMT joint when it is displaced. This re-establishes a medial reference for the remaining reconstruction. Temporary fixation holds the reduction while it is checked. In my practice, low-profile locking plates from systems such as DePuy Synthes or Paragon may be used according to availability and fracture requirements. Their mention describes the implants used in my practice and does not imply comparative superiority.

The second metatarsal is then reduced into its relationship with the intermediate cuneiform. A pointed reduction clamp directed towards the medial cuneiform can assist, provided rotation, translation and column length are checked before definitive fixation. The third ray is reduced and stabilised when injured. Plates may support a fracture or bridge an injured joint; the mechanical role and the implications for later removal should be stated explicitly.

I try to avoid a routine home-run screw across the medial cuneiform to second-metatarsal interval when a plate construct provides satisfactory stability. However, this is a construct preference rather than a rule. If the Lisfranc interval remains unstable, it requires adequate stabilisation. An intercuneiform screw between the medial and intermediate cuneiforms addresses instability at that articulation; it is not automatically a substitute for fixation of a persistently unstable medial-cuneiform to second-metatarsal relationship.

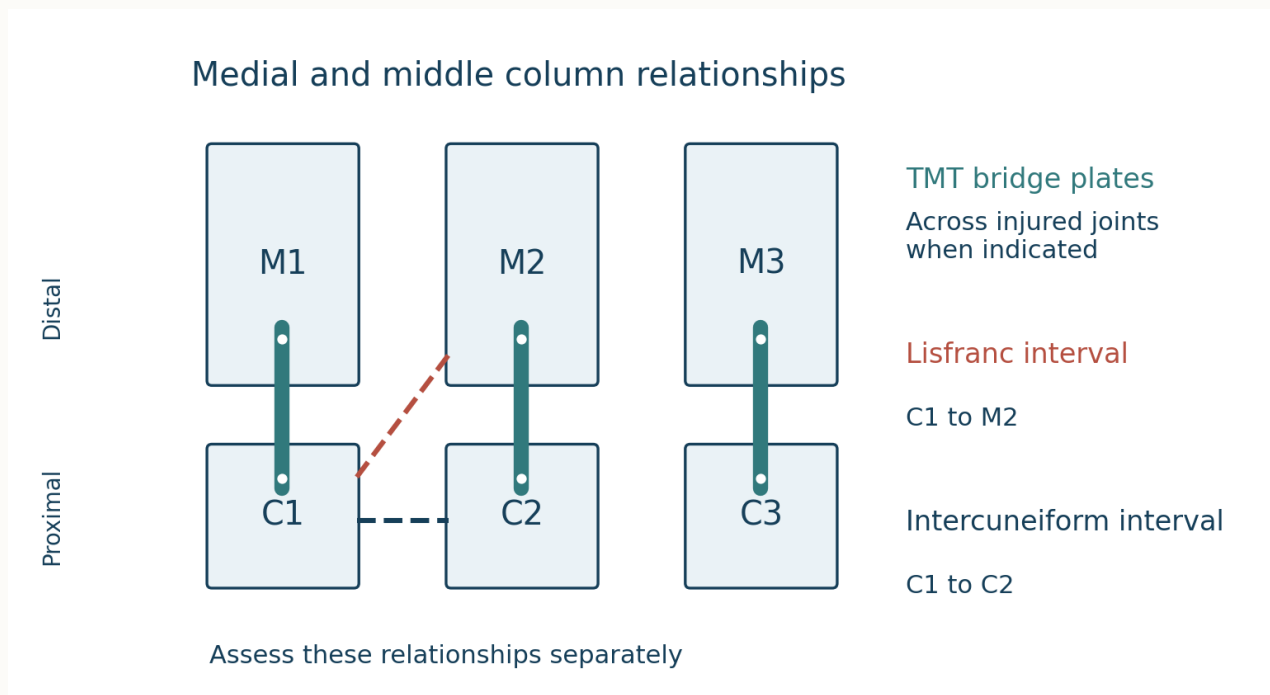


Figure 8.2 Conceptual distinction between TMT bridge fixation, the Lisfranc interval and intercuneiform fixation. C1, C2 and C3 denote the medial, intermediate and lateral cuneiforms; M1, M2 and M3 denote the corresponding metatarsals. Dashed lines mark relationships to assess, not mandatory screw trajectories. Diagram not to anatomical scale.

The fourth and fifth TMT joints are assessed after reconstruction of the medial and middle columns. Where temporary stabilisation is required, it should respect the mobility of the lateral column. Final assessment includes fluoroscopic congruity, clinical alignment, stability of the Lisfranc and intercuneiform intervals, and the absence of joint penetration by unintended screw trajectories. [T21]

Retention or removal of implants

My preference is to retain well-tolerated low-profile implants when the construct and reconstructed joints permit. In a patient with persistent implant-related midfoot pain or restriction, I consider removal after at least four months, provided healing is established and the foot will remain stable. This is an earliest point for consideration in selected cases, not a mandatory removal date.

Plates crossing unfused joints deserve a planned discussion about later removal because they constrain motion and may fatigue. Plates supporting a healed fracture or a fusion may be retained when asymptomatic. A trial of first-TMT bridge plating used planned removal at four to five months, but that protocol should not be applied indiscriminately to every Lisfranc construct. [T18]

Pain after fixation should first be localised. Post-traumatic arthritis, nonunion, recurrent instability, tendon irritation, nerve symptoms and complex regional pain syndrome may resemble implant discomfort. Removal exposes the patient to wound, nerve, infection and refracture risks, and it will not reliably relieve pain caused by an arthritic joint.

Metatarsal and toe fractures

Metatarsals

Many stable, acceptably aligned metatarsal fractures can be treated non-operatively. The examination nevertheless needs to exclude rotation, shortening, multiple-ray instability, open injury and an associated Lisfranc lesion. The first ray deserves particular attention because malalignment alters load transfer through the forefoot. Central metatarsal length and sagittal alignment influence plantar pressure and the risk of transfer metatarsalgia.

Surgery may be required for displaced or unstable patterns, important articular incongruity, unacceptable rotation or shortening, open fractures and selected multiple-ray injuries. In polytrauma, a stable construct may simplify nursing, mobilisation and management of the overall limb, but polytrauma alone is not an indication to fix every metatarsal. Kirschner wires, intramedullary screws and low-profile plates are selected according to fracture location, tissue condition and the stability required. [T22]

Proximal fifth-metatarsal injuries need separate recognition. A tuberosity avulsion, a fracture at the metaphyseal-diaphyseal junction and a proximal diaphyseal stress injury have different healing behaviour. These should not all be treated as interchangeable minor fractures. Patient activity, displacement, healing risk and the precise zone influence protection and the consideration of surgery.

Toes

Stable, closed lesser-toe fractures are commonly managed with buddy strapping, skin protection and a stiff-soled shoe. Rotation and unacceptable angulation should be corrected rather than simply strapped in place. The hallux has a greater role in push-off and balance, and displaced articular or unstable hallux injuries warrant particular attention. [T23]

An open toe fracture requires assessment of the wound, contamination, nail bed, perfusion and fracture stability. It does not automatically require a wire. Wound care, antibiotics when indicated and appropriate debridement come first; fixation is added when instability, displacement or the soft tissue reconstruction requires it. A small wound should not conceal an unrecognised open fracture or tendon injury. [T1, T23]

Rehabilitation and functional recovery

The rehabilitation plan begins before definitive fixation. The patient needs a clear account of weight-bearing restrictions, elevation, wound review, analgesia and how to obtain help if symptoms deteriorate. Physiotherapy and occupational therapy assess transfers, stairs, walking aids, home access and the ability to comply with the proposed loading plan. Recovery is affected by the condition of the whole patient, not only the strength of the implant.

Early movement and loading can be beneficial when the tissues and construct allow them. The WAX trial supports weight bearing from two weeks after surgery in selected adults with operatively treated ankle fractures. Its findings should not be transferred

automatically to pilon, talar, calcaneal, navicular or Lisfranc injuries, or to patients with significant neuropathy or other exclusions. These injuries require their own assessment of union, articular reconstruction and soft tissue protection. [T27]

Table 8.8 Follow-up priorities across the injury spectrum

Injury	Reconstruction to protect	Important later concerns
Pilon	Plafond congruity and distal tibial alignment	Wound failure, infection, nonunion and ankle arthritis
Ankle	Mortise, fibular rotation and syndesmotic stability	Loss of reduction, stiffness and persistent instability
Talus	Joint congruity and viable bone	Osteonecrosis, collapse and ankle or subtalar arthritis
Calcaneus	Posterior facet and heel shape	Subtalar arthritis, varus, widening and tendon impingement
Navicular	Medial column length and articular alignment	Nonunion, osteonecrosis and column collapse
Lisfranc	TMT, Lisfranc and intercuneiform relationships	Recurrent instability, arthritis and implant symptoms
Metatarsals and toes	Rotation, length and plantar loading	Malunion, transfer pain and footwear difficulty

New severe pain, increasing swelling, wound drainage, fever, worsening numbness, colour change or symptoms suggestive of venous thromboembolism require timely clinical reassessment. Persistent pain is investigated according to its location and mechanism rather than automatically attributed to metalwork.

Return to work, driving and sport is individualised. Swelling and endurance often recover more slowly than radiographic union. Proprioception, calf strength, balance, footwear tolerance and confidence in the limb matter to the final outcome.

Patient-reported function and the ability to resume meaningful activities should accompany radiographs in the assessment of recovery.

Loading instructions must be understandable to the patient and the rehabilitation team. The 2024 BOAST recommends the terms non weightbearing, limited weightbearing and unrestricted weightbearing, with a status for each affected limb. For a restriction, the clinician should record why it is necessary, the permitted functional activities, duration and review plan, together with walking aids or braces. Restrictions should be expressed through permitted activities and distances, not percentages of body weight or kilograms. [T35]

The permission to load and the ability to load are different. A patient may be permitted unrestricted weightbearing yet need an aid because of pain, weakness or balance. Another may feel capable of walking but need protection because the reconstruction

remains vulnerable. Follow-up should resolve this distinction, check practical barriers and revise instructions as healing progresses. Weightbearing status should be reviewed at each follow-up rather than copied indefinitely from the first operation note. [T35]

Recognising the cause of a disappointing recovery

A patient who remains in pain deserves a renewed diagnosis. Start with the location, character and timing of symptoms. Pain on loading can arise from nonunion, malalignment, articular damage or altered pressure distribution. Burning discomfort and sensory disturbance suggest a different line of enquiry from a focal prominence beneath a shoe. Infection, recurrent instability and tendon dysfunction must remain in the differential where the clinical features support them.

Swelling can persist after substantial foot and ankle injury, but its trajectory matters. A gradually improving foot with activity-related swelling differs from a wound that becomes increasingly painful, red or draining. Investigations should answer the suspected problem. Plain radiographs demonstrate alignment and many features of healing; CT can clarify selected questions about union or joint morphology; blood tests, aspiration or tissue sampling may be relevant when infection is suspected. A single normal test should not close an investigation whose clinical premise remains strong.

Post-traumatic arthritis is discussed before reconstruction because cartilage can be injured beyond what fixation can reverse. If arthritis later becomes symptomatic, treatment returns to the principles set out elsewhere in this book: identify the painful joint, assess alignment and neighbouring movement, consider mechanical and nonoperative measures, and select reconstruction, fusion or replacement only when appropriate. Trauma surgery and elective foot surgery are therefore parts of one continuing responsibility for function.

The patient also carries the experience of the injury. Loss of work, interrupted sleep, fear of falling and uncertainty about future mobility can alter recovery. These issues should be acknowledged and addressed through the wider team when needed. A meaningful outcome includes the capacity to live and work with the limb, alongside union, infection control and anatomical restoration.

Closing perspective

The philosophy of foot and ankle trauma is to understand what has happened to the entire functional unit. The first responsibility is to preserve life, limb and viable tissue. Reconstruction then restores the geometry and stability needed for healing and movement. A classification helps describe the problem; it does not replace examination, CT interpretation, biological judgement or the patient's priorities.

In my practice, the recurring questions are practical. Is the skin safe? Is the talus centred? Has the articular surface been restored? Have the heel and the columns of the foot recovered their shape and length? Does the construct stabilise the structures that are actually injured? Can the patient safely follow the rehabilitation plan? Answering these questions provides a coherent basis for treatment from the distal tibia to the toes.

References for Chapter 8

- [T1]** British Orthopaedic Association. BOAST Open Fractures. December 2017. [Read source](#)
- [T2]** British Orthopaedic Association. BOAST The Management of Ankle Fractures. August 2016. [Read source](#)
- [T3]** AO Foundation. AO Surgery Reference. Complete multifragmentary articular and metaphyseal distal tibial fracture: ORIF through an anterolateral approach. [Read source](#)
- [T4]** AO Foundation. AO Surgery Reference. Distal tibia partial articular split fracture: definition. [Read source](#)
- [T5]** Joumah A, Bakhshayesh P. Identifying and Managing Atypical Ankle Fractures Beyond the Lauge-Hansen Classification System. BOFAS Glasgow meeting, November 2025. Poster P20. Conference abstract. [Read source](#)
- [T6]** Bakhshayesh research archive. Atypical Ankle Fractures Abstract. Author-held source manuscript, cited in the supplied chapter. The six-pattern extension in this chapter incorporates the author's current dictated framework.
- [T7]** AO Foundation. AO Surgery Reference. Displaced talar neck fracture: definition and Hawkins classification. [Read source](#)
- [T8]** AO Foundation. AO Surgery Reference. Displaced talar neck fracture: ORIF screw fixation. [Read source](#)
- [T9]** AO Foundation. AO Surgery Reference. Talar body fracture: ORIF screw and plate fixation. [Read source](#)
- [T10]** AO Foundation. AO Surgery Reference. Posterior process of the talus: definition and ORIF screw fixation. [Read source](#)
- [T11]** AO Foundation. AO Surgery Reference. Displaced fracture of the calcaneus body: definition and classification. [Read source](#)
- [T12]** AO Foundation. AO Surgery Reference. Displaced fracture of the calcaneus body: ORIF plate and screw fixation. [Read source](#)
- [T13]** Tanello T, Yousef A, Bakhshayesh P. A Novel Sinus Tarsi Approach and Standard Calcaneal Plate Application for Calcaneal Fractures. Author-held manuscript. Publication status unverified. Cited in the supplied chapter.
- [T14]** Bakhshayesh research archive. Whole manuscript Final Calcaneal Fracture Study. Author-held working version. Cited in the supplied chapter. Cited for technique description, not comparative efficacy or reconciled outcome estimates.
- [T15]** AO Foundation. AO Surgery Reference. Complete articular navicular fracture: ORIF navicular plate. [Read source](#)
- [T16]** Sangeorzan BJ, Benirschke SK, Mosca V, Mayo KA, Hansen ST Jr. Displaced intra-articular fractures of the tarsal navicular. J Bone Joint Surg Am. 1989;71(10):1504-1510. [Read source](#)
- [T17]** Philpott A, Lawford C, Lau SC, Chambers S, Bozin M, Oppy A. Modified Dorsal Approach in the Management of Lisfranc Injuries. Foot Ankle Int. 2018;39(5):573-584. [Read source](#)
- [T18]** Stødle AH, et al. Temporary Bridge Plating vs Primary Arthrodesis of the First Tarsometatarsal Joint in Lisfranc Injuries: Randomized Controlled Trial. Foot Ankle Int. 2020;41(8):901-910. [Read source](#)
- [T19]** Open Reduction Internal Fixation vs Primary Arthrodesis for Displaced Lisfranc Injuries: A Multicenter Randomized Controlled Trial. Foot Ankle Int. 2024;45(6):612-620. [Read source](#)
- [T20]** Stødle AH, et al. Outcome after nonoperative treatment of stable Lisfranc injuries. A prospective cohort study. Foot Ankle Surg. 2022. [Read source](#)
- [T21]** AO Foundation. AO Surgery Reference. Treatment of Lisfranc injuries. [Read source](#)
- [T22]** AO Foundation. AO Surgery Reference. Metatarsal fractures. [Read source](#)
- [T23]** AO Foundation. AO Surgery Reference. Lesser toe fractures: nonoperative treatment. [Read source](#)
- [T24]** AO Foundation. AO Surgery Reference. Transsyndesmotic lateral simple fracture with medial fracture: definition. [Read source](#)
- [T25]** AO Foundation. AO Surgery Reference. Complete multifragmentary articular and metaphyseal distal tibial fracture: ORIF through an anteromedial approach. [Read source](#)
- [T26]** Gardner MJ, et al. Secondary soft tissue compromise in tongue-type calcaneus fractures. J Orthop Trauma. 2008;22(7):439-445. [Read source](#)
- [T27]** Bretherton CP, et al. Early versus delayed weight-bearing following operatively treated ankle fracture (WAX): a non-inferiority, multicentre, randomised controlled trial. Lancet. 2024. [Read source](#)

[T28] National Institute for Health and Care Excellence. Fractures non-complex: assessment and management. NICE guideline NG38. [Read source](#)

[T29] AO Foundation. AO Surgery Reference. Osteonecrosis after talar injury. [Read source](#)

[T30] British Orthopaedic Association. BOAST Diagnosis and management of arterial injuries associated with musculoskeletal trauma. June 2026. [Read source](#)

[T31] British Orthopaedic Association. BOAST Diagnosis and Management of Compartment Syndrome of the Extremities. Updated July 2025. [Read source](#)

[T32] AO Foundation. AO Surgery Reference. Tibial shaft fragmentary segmental fractures. Bridge plating. [Read source](#)

[T33] AO Foundation. AO Surgery Reference. Suprapatellar intramedullary nailing of the tibial shaft. [Read source](#)

[T34] AO Foundation. AO Principles of Fracture Management. Principles of stability and biological fixation, external fixation and polytrauma. [Read source](#)

[T35] British Orthopaedic Association. BOAST Mobilisation and weightbearing after orthopaedic surgery and musculoskeletal injury. August 2024. [Read source](#)

[T36] Kougioumtzis IE, Chloros GD, Bakhshayesh P. Plate-Assisted Intramedullary Nailing of Distal Tibia Fractures. Sultan Qaboos University Medical Journal. 2024;24(1):115-118. doi:10.18295/squmj.9.2023.054. [Read source](#)

[T37] Raufi MY, et al, Bakhshayesh P. Intramedullary Fibular Nail Versus Plate Fixation for Adult Lateral Malleolus (Fibula) Fractures: A Systematic Review and Meta-Analysis. Cureus. 2025;17(12):e100074. doi:10.7759/cureus.100074. [Read source](#)

[T38] Ismayl G, Afzal S, Al Najjar M, Ammar MS, Khunda A, Sprott D, Rafee A, Bakhshayesh P, Foster P. Long hindfoot nail fixation using standard tibial nails for elderly ankle and distal tibia fractures. Injury. 2025;56(10):112648. doi:10.1016/j.injury.2025.112648. [Read source](#)

[T39] Bakhshayesh P. Tibial and long bone fractures. Author patient information. Prepared 10 October 2026. [Read source](#)

[T40] Bakhshayesh P. Pilon fractures. Author patient information. Prepared 10 October 2026. [Read source](#)

[T41] Bakhshayesh P. Calcaneus fractures. Author patient information. Prepared 10 October 2026. [Read source](#)

[T42] Bakhshayesh P. Lisfranc injury. Author patient information. Prepared 10 October 2026. [Read source](#)

[T43] Bakhshayesh P. Ankle fractures. Author patient information. Prepared 10 October 2026. [Read source](#)

CHAPTER 09

09 Recovery and the measure of success

The operation is part of a longer responsibility

A reconstruction is undertaken for the life the patient hopes to recover. Its success cannot be judged solely from the wound, the position of an implant or the appearance of a radiograph. These findings matter, but they are intermediate observations. The patient asks whether walking is easier, whether work is possible, whether sleep has improved and whether the foot can be trusted. I therefore consider recovery part of the original treatment decision. The choice of procedure, the protection it requires and the rehabilitation that follows should belong to one coherent plan.

The relationship between biology, mechanics and function continues after surgery. Skin may heal while bone remains vulnerable. Bone may unite while the calf remains weak. A stable correction may still feel unfamiliar during walking, especially after months of altered loading. These differences explain why a patient can be told that an operation has healed yet still struggle in everyday life. Good follow-up makes those distinctions explicit and identifies what is needed next rather than using one milestone to stand for the entire recovery.

Prepare the practical recovery before admission

Elective care allows time to prepare for temporary dependence. I ask how the patient will enter the home, use stairs, wash, prepare food and reach the bathroom if loading is restricted. The condition of the opposite leg, upper-limb strength, balance, vision and general endurance may determine whether crutches are practical. A walking aid should be selected and taught, not merely issued. Occupational therapy and physiotherapy can identify problems that are difficult to appreciate from a consultation-room chair. Where recovery is not feasible at home, this needs a plan before surgery.

Prehabilitation also means preserving what can safely be preserved: general conditioning, appropriate strength, nutrition and confidence with the expected aids. It is not an instruction to train through worsening pain or load an unstable injury. The Centre for Perioperative Care supports preparation that connects exercise and medical optimisation with nutrition, smoking cessation, mental wellbeing and practical arrangements. For an individual patient, the useful programme is the one that fits their condition and resources. An achievable preparation plan is preferable to a long list of ideal changes that cannot be sustained. [R1]

Acute trauma removes much of this preparation time, but the same questions arise as soon as the patient is stable. The rehabilitation plan should develop alongside definitive treatment. BOAST guidance for admitted trauma patients calls for an early rehabilitation prescription that accompanies transfer and discharge and records treatment, therapy needs, goals, wound care, medicines and follow-up. Clear communication is particularly important when care moves between a major trauma

centre, a local hospital and community services. The patient should not become the only person carrying the plan between teams. [R2]

Different tissues reach different milestones

Early recovery is dominated by comfort, circulation, swelling, wound protection and safe mobility. A satisfactory wound review is encouraging, but it does not establish the strength of a tendon repair, ligament reconstruction, osteotomy or fusion. The schedule must reflect the structure that needs protection. Moving a joint after a simple arthroscopic procedure and moving it after cartilage restoration are different decisions. Likewise, exercises appropriate after cheilectomy may be inappropriate across a first metatarsophalangeal fusion.

During later recovery, the emphasis shifts towards union or tissue healing, permitted motion and useful loading. Clinical examination and appropriate imaging help determine whether progression is justified. The absence of pain alone is insufficient in a patient with neuropathy, and persistent swelling does not by itself prove failure. I look at the trend, the pattern of symptoms, the examination and the mechanical demands being placed on the limb. Recovery is assessed through several observations rather than a single reassuring image or an arbitrary date.

Functional recovery commonly extends beyond early tissue healing. Gait, endurance, strength, balance and confidence must be rebuilt, and some limitations are an intended consequence of treatment. A fused joint will remain stiff; rehabilitation should help the patient use the motion that remains. An ankle replacement needs long-term observation as well as early rehabilitation. Explaining these distinctions helps patients recognise real progress without mistaking every residual symptom for failure or every improvement for permission to resume unrestricted activity.

Recovery progresses along different pathways

Wound healing, structural healing and useful function are related, but they are not the same milestone.

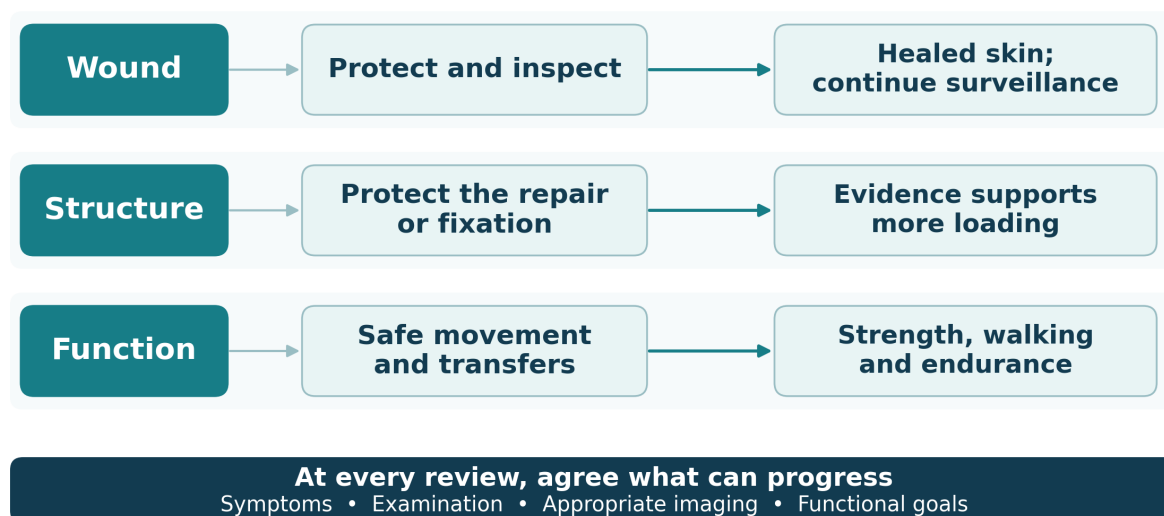


Figure 9.1. Wound healing, structural healing and functional recovery progress along related but distinct pathways. Arrows represent clinical progression, not a fixed timescale. Loading and exercise advance according to the individual procedure, examination, relevant imaging and agreed goals.

Write weight-bearing instructions that can be followed

The weight-bearing prescription should name the affected limb and describe what the patient can actually do. The 2024 BOAST standard uses three categories: non weightbearing, limited weightbearing and unrestricted weightbearing. Where loading is restricted, the reason, practical limits, duration and review plan should be recorded, together with necessary aids or a brace. Its emphasis is on clear functional or distance restrictions rather than percentages of body weight. Instructions need review as healing and mobility change. [R3]

This approach is valuable because patients do not live in percentages. They need to know whether they may stand for a transfer, walk indoors, negotiate stairs or remove a boot for a specified activity. A statement that loading is limited should therefore lead to a demonstration and a check that it is achievable. If a patient cannot comply because of frailty, another injury or the home environment, repeating the instruction is not enough. The team must reconsider the aids, support, rehabilitation setting or, where appropriate, the treatment strategy.

Earlier loading can be valuable when the injury, fixation, soft tissues and patient allow it, but a general preference for mobilisation is not permission to load every repair early. A pilon reconstruction, an Achilles repair, a neuropathic reconstruction and an uncomplicated stable ankle injury do not share one timetable. When restrictions are necessary, preserve safe activity elsewhere and explain the review point. The objective is to protect the structure being healed while avoiding unnecessary loss of independence and conditioning.

Wounds, casts and swelling need an accessible plan

The patient should leave with clear instructions about dressings, wound review, cast or boot care and whom to contact if something changes. A protective device can itself create harm if pressure is excessive, fit changes with swelling or the patient cannot recognise a skin problem. Increasing focal pressure, new numbness, colour change, a cold foot or unexpectedly severe pain requires prompt assessment. A patient with impaired sensation may need another person or a clinical service to help with appropriate skin surveillance.

Swelling often varies with activity and dependency, and may persist after early wound healing. The important question is whether its pattern fits the expected recovery. Spreading redness, new discharge, fever, deterioration after initial improvement or a wound that opens should trigger clinical review rather than reassurance by telephone alone. General postoperative education should distinguish expected discomfort from symptoms that require an examination. Detailed wound treatment belongs to the treating team, who know the operation, the tissue condition and any microbiology.

I aim for a plan that is simple enough to use on a difficult day. The patient should know the next appointment, the intended loading status, the medicines they are expected to take and the contact route for a concern. The quality of the written instructions matters, but so does whether the telephone number connects to someone who can arrange appropriate help. Service organisation becomes a clinical intervention when it allows a problem to be recognised and treated before it becomes more serious.

Prevent thrombosis through individual assessment

Reduced mobility, injury and surgery can increase the risk of venous thromboembolism, while preventive anticoagulation carries bleeding risks. The decision requires assessment of the patient and the treatment pathway. NICE recommends considering pharmacological prophylaxis for foot or ankle surgery requiring immobilisation, prolonged anaesthesia or an individual balance in which thrombosis risk exceeds bleeding risk. For lower-limb immobilisation it also advises considering whether prophylaxis should stop if immobilisation extends beyond 42 days. This is a review threshold, not a universal prescription or a reason for patients to change treatment themselves. [R4]

The discharge plan should state whether prophylaxis is required, how it is administered, its intended duration and whom to contact about a problem. Patients should understand that being in a boot, taking an anticoagulant or moving a little does not eliminate every risk. New calf swelling or pain needs urgent assessment; sudden breathlessness, chest pain, collapse or coughing blood may indicate a serious emergency and requires emergency help. In the United Kingdom, call 999 for severe symptoms. Safe mobilisation and the prescribed preventive measures should remain part of the broader recovery plan.

Rebuild capacity rather than chase a calendar

Rehabilitation should connect a permitted movement with a useful task. Restoring safe ankle motion may improve progression over the foot; rebuilding calf strength may improve push-off; balance work may restore control after instability. These goals overlap but they should be chosen deliberately. Repeating an exercise because it appears on a standard sheet is less useful than understanding which limitation it is intended to improve. The patient also needs to know how to recognise an excessive response and when to seek an adjustment.

I look for progression in the quality and tolerance of activity. Can the patient walk a little further without a deterioration that overwhelms the following day? Is the gait becoming more efficient? Does balance improve as support is reduced? A return to ordinary footwear may be a useful milestone, but the footwear must still accommodate the foot and any swelling. Some patients will continue to need an orthosis or brace, and that may be compatible with a successful result.

Sport places demands beyond comfortable daily walking. Running, jumping, cutting and repeated exposure under fatigue require different capacities. Clearance should therefore consider the repaired structure, strength, control, symptoms and the actual activity rather than elapsed time alone. A patient recovering from Achilles rupture may regain a satisfactory walking pattern while still lacking the endurance for repeated propulsion. Similarly, a reconstructed ligament may feel stable before the person has regained reliable sport-specific movement control.

Work and driving are functional decisions

The label of an occupation rarely describes its full demands. A desk-based worker may still have a long commute and several flights of stairs; a manual worker may be able to return to temporary seated duties. I ask about prolonged standing, carrying, ladders, uneven surfaces, protective footwear and the ability to take breaks or elevate the limb. A phased return can be more realistic than a single date on which every work demand is expected to resume. The plan should be reviewed if symptoms, healing or available duties change.

Driving requires adequate control of the vehicle and an ability to respond safely, including during an emergency. The operated side, vehicle transmission, immobilisation, pain, strength and sedating medication all matter. The patient should obtain individual advice and check the current DVLA requirements and insurance position. UK guidance requires notification in some circumstances, including inability to drive for more than three months because of a broken limb. A generic postoperative interval cannot establish fitness to drive for every patient or vehicle. [R5, R6]

These discussions should take place early enough for the patient to arrange transport and employment support. Uncertainty should be acknowledged rather than converted into a promise. It is reasonable to provide an estimated range and explain which findings will govern the next decision. The useful question is whether the patient can meet the demands safely and repeatedly, not whether the date on the original discharge leaflet has arrived.

Persistent pain deserves a fresh assessment

Pain that does not follow the expected course should lead back to a diagnosis. I review the site, character and timing of symptoms, the original indication, the operation and the course of healing. Infection, delayed union, nonunion, loss of alignment, implant problems, tendon pathology, nerve injury and pain from a neighbouring joint may need consideration. An apparently satisfactory radiograph does not exclude every cause. Equally, visible metalwork is not automatically the explanation. The investigation should follow the new clinical question.

Complex regional pain syndrome is one possible cause of disproportionate continuing pain with sensory, vasomotor, swelling or sweating, and motor or trophic changes. Diagnosis is clinical, uses accepted criteria and requires consideration of better explanations. The Royal College of Physicians supports early recognition, appropriate rehabilitation and specialist referral when needed. A painful stiff swollen foot should not be labelled CRPS simply because the first investigation is unrevealing. When CRPS is suspected, pain, physical rehabilitation and psychological support should be coordinated without implying that the patient's symptoms are imaginary. [R7]

Sleep disturbance, fear of loading and distress can make recovery more difficult and deserve attention in their own right. A patient who has lost confidence after major injury may need explanation, graded rehabilitation and psychological support as well as an assessment of the reconstruction. Listening carefully does not require accepting an incorrect anatomical explanation; it requires taking the experience seriously while

working towards a useful one. Reassurance is strongest when it rests on an examination and a plan.

Measure the result that the patient experiences

Outcome assessment begins before treatment, when the original symptoms and functional goals can still be recorded. I want to know what changed in pain, walking, footwear, independence, work and participation, alongside the clinical findings. Patient-reported outcome measures provide a consistent method of following these domains. The BOFAS Registry includes measures such as the Manchester-Oxford Foot Questionnaire, EQ-5D and condition-specific scores, together with clinical and complication information. These instruments support comparison over time, but they do not replace the consultation. [R8]

A score should be interpreted with its baseline, timing and context. A patient can show a worthwhile improvement and still have a substantial disability; another may have a technically excellent correction but remain dissatisfied because the expected benefit was poorly defined. Complications, additional procedures and the burden of recovery should be counted alongside improvement. Results from selected patients who complete follow-up should not be presented as if they describe every person treated.

For the surgeon and the service, measurement is a means of learning. Repeated difficulty with wounds, delayed rehabilitation or unmet expectations should prompt examination of selection, technique and organisation. It is important to distinguish a difficult case mix from a preventable process problem without using either explanation automatically. A philosophical approach to surgery should remain open to evidence from its outcomes. The purpose is to improve future decisions, not simply to produce a favourable figure.

When revision is being considered

Revision surgery requires an explanation of why the first treatment has not produced an acceptable result. The problem may be biological, mechanical, infective, neurological or a combination. Before proposing another operation, I review the original records, available images and the patient's present priorities. Additional investigation should address a defined uncertainty, such as union, implant stability, alignment or possible infection. In complex cases, discussion with reconstructive, infection, vascular, plastic-surgical or pain colleagues can change what is possible and what is wise.

The next intervention should address an identified cause and a realistic functional goal. Removing an implant, revising a fusion or converting an unsuccessful replacement to another reconstruction each has consequences for bone, soft tissues and future options. Sometimes the better next step is further rehabilitation, footwear adaptation, medical treatment or observation. A further operation is justified by its expected benefit for the patient, not by the discomfort of accepting an imperfect initial result. The consent discussion should acknowledge the additional uncertainty and the possibility of staged treatment.

Three hypothetical teaching cases

The following cases are constructed teaching examples, not reports of patients treated by the author. They illustrate how the same principles connect assessment with recovery without implying a particular outcome.

Case one: painful ankle arthritis in a person who provides daily care for a partner. The images show advanced disease, but the decisive practical issue is whether the household can manage a period of restricted mobility. The consultation compares continued bracing with fusion and replacement, examining suitability and the importance of retained movement. Before elective surgery is chosen, the team explores temporary support, transfers, access and transport. The lesson is that recovery logistics belong within the indication for surgery. A technically appropriate operation may need a different timing or pathway to become a workable treatment.

Case two: a diabetic patient with neuropathy develops a hot swollen foot after increased walking. Pain is modest and the initial concern is a new flatfoot shape. The correct first decision is urgent specialist assessment for active diabetic foot disease, including possible Charcot neuroarthropathy, with protection while definitive management is arranged. Ordinary exercise progression or reassurance based on limited pain would miss the biological problem. The lesson is that symptoms cannot be interpreted without sensation and tissue risk; urgency is established before a deformity correction is discussed. [R9]

Case three: a manual worker remains weak and swollen after a complex calcaneal fracture has united. The patient is disappointed because bone healing was understood to mean full recovery. Reassessment considers subtalar symptoms, heel shape, footwear, calf strength and the demands of ladders and uneven ground. Rehabilitation and work modifications are reviewed, with further investigation only where it could change management. Later reconstructive options may be discussed if a defined painful mechanical problem persists. The lesson is to distinguish union from capacity and to explain both before the patient confronts the demands of employment.

Return to the original purpose

The measure of success is a reasoned comparison between the life interrupted by the condition and the life possible after treatment. Sometimes this means preserving motion, sometimes accepting a fusion to gain comfort and stability, and sometimes choosing supportive care. The patient should understand the remaining limitations as well as the gains. A good result does not require an ideal foot; it requires a treatment whose benefit is meaningful, whose consequences were understood and whose course was supported.

My responsibility is to connect the first explanation with the final review. Assessment, treatment, rehabilitation and outcome measurement are parts of one undertaking. The service must remain available when recovery diverges from the expected path, and the surgeon must be willing to reconsider the explanation. Technical skill matters most when it is joined to sound judgement, clear communication and sustained attention to the person who must live with the result.

References for Chapter 9

[R1] Centre for Perioperative Care. Assessment, optimisation, shared decision making: preparation for surgery. [Read source](#)

[R2] British Orthopaedic Association. BOAST: Rehabilitation and Communication with Trauma Patients. August 2016. [Read source](#)

[R3] British Orthopaedic Association. BOAST: Mobilisation and weightbearing after orthopaedic surgery / musculoskeletal injury. August 2024. [Read source](#)

[R4] NICE. Venous thromboembolism in over 16s: reducing the risk of hospital-acquired deep vein thrombosis or pulmonary embolism. NG89, lower-limb immobilisation and foot/ankle surgery recommendations. [Read source](#)

[R5] Driver and Vehicle Licensing Agency. Surgery and driving. Current GOV.UK guidance. [Read source](#)

[R6] Driver and Vehicle Licensing Agency. Broken limbs and driving. Current GOV.UK guidance. [Read source](#)

[R7] Royal College of Physicians. Complex regional pain syndrome in adults: UK guidelines for diagnosis, referral and management in primary and secondary care. Second edition, 2018. [Read source](#)

[R8] British Orthopaedic Foot & Ankle Society. BOFAS Registry: patient-reported outcomes, clinical data and follow-up pathways. [Read source](#)

[R9] NICE. Diabetic foot problems: prevention and management. NG19, recommendations on Charcot arthropathy. [Read source](#)

Condition directory

Use this directory alongside the contents. Clinical problems may involve more than one region; links identify the main discussion and useful companion chapters.

Condition or question	Main chapters
Ankle arthritis	3, 2, 9
Ankle fusion	3, 9
Total ankle replacement	3, 9
Ankle arthroscopy	3, 7
Chronic ankle instability	3, 7
Subtalar and hindfoot fusion	3, 4
Midfoot arthritis and fusion	4
Bunions and hallux valgus	5
Hallux rigidus and big toe arthritis	5
Hammer toe and claw toe	5
Lesser toe deformities and plantar plate injury	5, 7
Morton's neuroma	5
Progressive collapsing foot deformity	4, 3, 6
Cavovarus and the high arched foot	3, 4, 6
Plantar fasciitis and heel pain	7
Achilles tendinopathy and Haglund heel	7
Achilles tendon rupture	7
Painful accessory navicular	4
Ankle fractures	8
Pilon fractures	8
Lisfranc injury	8, 4
Calcaneus fractures	8, 6
Tibial and long bone fractures	8
Talar fractures and osteochondral lesions	8, 7
Gait and radiographic angles	6
Preparation and rehabilitation	2, 9

Terms used in the book

Arthrodesis Surgical fusion of a joint, intended to achieve a stable bony union in a useful position.

Arthroplasty Reconstruction or replacement of a joint; total ankle replacement is one specific form.

Arthroscopy Surgery using a small camera and instruments within a joint.

BMAC Bone marrow aspirate concentrate; a heterogeneous preparation whose composition and evidence depend on its use.

Cavovarus A high arch associated with a varus tendency of the hindfoot; its cause and flexibility require assessment.

Cheilectomy Removal of impinging osteophytes; this does not regenerate diffuse lost cartilage.

Chopart joint The transverse tarsal joint complex, comprising the talonavicular and calcaneocuboid articulations.

Diamond Concept A framework connecting cells, scaffold, signals and mechanical stability, with vascularity and the host also essential.

Hindfoot The talus and calcaneus and their functional relationships; the ankle is discussed alongside them in this book.

Lisfranc complex The tarsometatarsal region and ligamentous stabilisers linking the midfoot and metatarsal bases.

MTP joint Metatarsophalangeal joint, at the base of a toe.

Nonunion Failure of a fracture, osteotomy or intended fusion to unite within the expected clinical course; diagnosis uses the whole assessment.

Osteotomy A controlled division of bone to change alignment, shape or loading.

PCFD Progressive collapsing foot deformity, a three-dimensional condition involving ligament, tendon, joint and alignment changes.

PRP Platelet-rich plasma; clinical effects depend on indication and preparation and do not imply proven tissue regeneration.

Syndesmosis The distal tibiofibular ligamentous complex, essential to ankle mortise stability.

TMT joint Tarsometatarsal joint.

Weightbearing status A clear prescription for how the limb may be loaded, including practical restrictions, aids, duration and review.

Source notes and related publications

The principal author sources are the seven supplied chapter manuscripts dated 14 October 2026: Preface and Introduction; Hindfoot; Midfoot Conditions; Forefoot Conditions; Biomechanics of the Foot; Sports Injuries; and Foot and Ankle Trauma. The supplied Chapter 1 PDF is a second rendering of the opening manuscript and has not been counted as a separate chapter.

Relevant author-held material in Google Drive includes the completed Painful Accessory Navicular teaching presentation, atypical ankle-fracture abstract, calcaneal reconstruction manuscripts and the earlier Regenerative Care compilation. Original figure credits are retained in the chapter captions. Preliminary series with inconsistent draft denominators were used only for the described clinical concepts, without importing outcome claims.

The author's previous books *Philosophy of Major Trauma* and *Regenerative Care in Trauma and Orthopaedics* provide the philosophical and visual continuity of this edition. Their consistent theme is that mechanism, tissue viability, organisation of care and functional recovery belong in the same clinical decision.

The author's clinical website material was reviewed across ankle arthritis, fusion, replacement, arthroscopy, instability, hindfoot and midfoot reconstruction, forefoot conditions, deformity, tendon disorders and fractures. Earlier Leeds website descriptions were reconciled with current professional information. The current condition guides complement this book with shorter patient explanations.

Two additional supplied resources were read as background: *Surgery of the Foot & Ankle*, a rheumatoid-foot patient resource, and *Foot & Ankle Surgery Leaflet Advice*, a hospital procedure-information compilation supplied with a .crdownload suffix but readable as a PDF. Their third-party text and images are not republished wholesale. The book's clinical discussion and references provide the integrated treatment account.

Bibliographies are chapter-specific to keep the source of a clinical statement visible. Some professional educational pages summarise established practice; original trials, guidelines and consensus papers are identified where available. Author archive references without public links retain their manuscript status. No claim is made that this narrative book exhausts the literature.

Professional clinical website

<https://peymanorthopaedics.world/>

Leeds foot and ankle website

<https://www.ankleandfootsurgeryleeds.co.uk/>

Public writing and books

<https://seculardemocraticiran.world/>

The measure of surgery is the life that becomes possible afterwards.

Mr Peyman Bakhshayesh | MD, PhD, MBA