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Consensus of the 13th Round Table York, June 2026

The Forefoot and Midfoot Revisited

Henry Bowyer
Mohammad Jabaiti
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Consensus of the 13th Round Table
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Course Facilitators:
Dishan Singh
Tim Williams

Chairpersons:
Carolyn Chadwick
Robert Clayton
Anand Pillai
Roland Walker
Tim Williams

Hosted by:
Ortho Solutions UK Ltd.



Distilled in this document are the thoughts and opinions, with consensus where possible, of 25 Orthopaedic Foot and Ankle Consultant Surgeons who gathered from across the United Kingdom. A basis of invited lectures introduced open and frank discussion from which consensus was sought. The statements herein only represent those of individuals and no claim is made that they are irrefutable. All the percentage figures quoted represent the proportion of the surgeons present who voted on the subject in discussion.

Preface

The Round Table meetings have become an established annual consensus meeting since the first get together held in Padua, Italy in June 2011.
About 25 senior members of BOFAS meet in a hotel setting for 3 days to discuss selected topics with ample time for an informal discussion. This Round Table approach is conducive to a more effective learning experience and generates considerable debate, but the group is able to reach a consensus on many issues. The proceedings of the meeting, the literature review, the personal experience, the discussions and the consensus views of all those who participate are collated in this booklet with the thorough, skillful and diligent assistance of 2 scribes (Henry Bowyer and Mohammad Jabaiti).

The theme for the York 2026 Round Table was the Forefoot and Midfoot revisited and I am grateful to Tim Williams who acted as co-facilitator for this meeting.

Ortho Solutions UK Ltd. have kindly provided financial and administrative support to the meeting since its inception. I would like to express my gratitude to Emma Keech and Sheena Easton for their hard work in ensuring the smooth running of the course.

This booklet collates the literature review and the views of all those who participated. This booklet does not represent Level I evidence derived from prospective randomized controlled trials but represents the compilation of the combined experience of the 25 British participants.

We have selected a short list of references to keep the booklet concise and easily readable.

I hope that you will find something of use and relevant to your own practice.

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Summary of Sessions

Session 1	**The First Ray**	**Chair:** *Rob Clayton*
1.1	Pathomechanics of Hallux Valgus	James Ritchie
1.2	MIS for Hallux Valgus: are we there yet?	Lyndon Mason
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Session 1: The First Ray

Chaired by Robert Clayton

1.1. Pathomechanics of Hallux Valgus — *James Ritchie*

Stabilisers of the first metatarsal

- The stabilising components of the first metatarsal consist of osseous and soft tissue structures. The sesamoids are held in place by the deep transverse ligaments however their efficacy is dependent on soft tissues.
- Soft tissue stabilisers consist of the medial capsule and medial sesamoid ligaments as well as the sling action of peroneus longus on the first metatarsal. The action of peroneus longus maintains plantar flexion. Tensioning of the peroneus longus has been shown to reduce the intermetatarsal angle in a cadaveric study with the caveat of worsening rotation and reducing Meary's angle (without the opposing action of tibialis anterior)(1).
- The Windlass mechanism infers stability through dorsiflexion of the hallux, leading to tightening of the plantar fascia and resultant locking of the first metatarsal over the sesamoids. The Windlass mechanism is dependent on correct alignment of osseous components. For example, increasing the intermetatarsal angle and subluxing the metatarsal head medially on cadaveric models has been found to defunction the Windlass mechanism(2).

Pathogenesis of Hallux Valgus

1. The first metatarsophalangeal joint medial collateral and medical sesamoid ligaments fail resulting in loss of medical constraints and medical metatarsal head drift(3).
2. The proximal phalanx is pulled valgus by the adductor hallucis and the deep transverse ligament.
3. Pressure from shoes makes the medical bursa swell.
4. Subluxation of the metatarsophalangeal joint medially with uncoverage of the sesamoids results in eccentric action of extensor hallucis longus and flexor hallucis longus which become lateral deforming forces.
5. The metatarsal head pronates due to abductor hallucis defunctioning with preservation of adductor hallucis function.

- This model continues to provide a good basis for the aetiology of hallux valgus however it fails to address the role of the tarsometatarsal joint in the deformity. Additionally hallux valgus pathogenesis is likely to occur as a composite movement with simultaneous steps rather than step-wise progression.

Why do these processes occur in the first place?

- Deformity occurs when the forces creating it overpower those resisting. This can be considered as either a situation in which an abnormal force is applied to a mechanically normal foot or one in which a mechanically compromised foot fails under normal load.

Predisposing Factors for Hallux Valgus:

- Increasing age and obesity are predominant risk factors for the development of hallux valgus. Although female sex is often considered to be a significant risk factor, studies indicate that the ratio between men and women with hallux valgus is quite similar with a ratio of 1:1.6(4). This is not reflected in those presenting to outpatient clinics or undergoing surgery.
- There is a strong genetic basis for hallux valgus, particularly in those occurring in earlier life. There is strong evidence for maternal transmission in juvenile hallux valgus with 72% of cases having a genetic association(5). In adult onset cases approximately 83% of cases have been found to have a positive family history although this includes any relative(6). Genetics are likely to have an impact on contributing factors such as hypermobility, metatarsal morphology and the forefoot shape and metatarsal arcade. One likely confounder to this may be the behavioural or cultural preferences within a family unit regarding shoewear choice.

Role of Anatomic Variation in Hallux Valgus

- Tibialis anterior inserts variably at the midfoot and forefoot with 5 different types described. In the type where it inserts predominantly of the first metatarsal it results in increased deforming forces with inversion and dorsiflexion(7).
- The variant connections between tibialis posterior and the plantar muscles of the foot have been associated with hallux valgus severity(8). These can include tibialis posterior to flexor hallucis brevis or adductor hallucis or both. Single connections have been shown to have a high association with hallux valgus whilst cross connections involving both FHB and ADH have an even higher association.
- Facet configuration, particularly the number of facets, of the proximal fist metatarsal articular surface has been shown on cadaveric models to correlate with the incidence of hallux valgus(9). In cases of hallux valgus the first metatarsal uniformly had the ‘flat type’, unifaceted surface. In trifaceted cases no hallux valgus was observed. There is a significant correlation between ‘continuous flat’ type morphology and increased degree of hallux valgus and increasing intermetatarsal angle(10).

- The morphology of the first metatarsal head also appears to have a bearing on the development of hallux valgus. ‘Dome type’ metatarsal heads appear to be associated with deformity severity proportional to radius of curvature(11). Conflicting studies have also reported on the significance of the first metatarsal length as an independent risk factor for hallux valgus. Increased metatarsal length is a likely association for hallux valgus in men(12). The measurements that inform the evidence for metatarsal morphology and length have invariably been taken from radiographs. The weakness of this methodology is that metatarsal head shape is highly dependent on rotation on an X-ray(13). Furthermore measuring metatarsal length on plain dorsoplantar films may not be accurate given the variable inclination or pitch (i.e cavus vs planus foot).
- First metatarsal torsion and tarsometatarsal pronation may also contribute to deformity. A cadaveric study of osteotomised first metatarsals demonstrated that hyperpronation and increased torsion reproduced hallux valgus(14).

The Role of Sagittal Plane Instability

- There is a long standing association between TMT instability and HV first described nearly 100 years ago(15). The degree of sagittal plane instability at the TMT has been shown to correlate with the incidence but also the severity of hallux valgus deformity(16,17).
- There remains a challenge in both defining and measuring tarsometatarsal instability. Excessive dorsoplantar translation beyond 8mm has been posited as an objective limit(18). The direction of instability is contentious with dorso-medial translation being posited as a more relevant biomechanical metric(19).
- Instability observed in clinical examination may not be accurate and the role of contributions from neighbouring joints, including the talonavicular and naviculocuneiform joints, may be frequently overlooked(20,21,22). Clinical examination is unlikely to adequately isolate the 1st tarsometatarsal joint. Wider fusion beyond the tarsometatarsal joint may be indicated in cases of sagittal plane instability(23).

Association Between Hallux Valgus and Hallux Rigidus(24)

- The deformity is precipitated initially by an increased ground reaction force under the first metatarsal head. This could be due to a plantarflexed first ray, hind foot eversion of forefoot valgus or a combination of the three.
- The resultant dorsiflexion and inversion at the naviculocuneiform joint and first tarsometatarsal joint limits first metatarsophalangeal joint dorsiflexion. This in turn affects the axis of motion of the first metatarsophalangeal joint with reduced sagittal motion and increased transverse motion.
- This ultimately increases contact pressures on the lateral aspect of the hallux with resultant sesamoid subluxation(24).

The Association Between Hallux Valgus and Pes Planus

- Multiple studies have demonstrated a clinical and radiological association between hallux valgus and pes planus with some evidence of proportionality(25-28). Individuals with hallux valgus have been shown to have increased hindfoot eversion and midfoot dorsiflexion in terminal stance(29). This indicates hallux valgus is associated with a flexible foot which doesn't suppress dynamic deformation of hindfoot and midfoot in gait.

The Role of Shoes

- There is some historical evidence to suggest that shoe wearing may be an independent risk factor for developing hallux valgus. A 1958 paper studying shoe-wearing and non shoe-wearing population in Hong Kong showed a 33% vs 2% prevalence respectively(30), but the 2 populations had different ethnic origins.
- Studies looking at cemetery remains have found significant differences in hallux valgus prevalence between men and women at different points in history, as well as differences between genders over time(31,32). This likely correlates with changes in footwear fashion.

Synthesis

- All studies to date present associations with many exceptions and it is therefore difficult to draw a definitive, causative link. It remains unclear whether the hindfoot deformity drives the forefoot deformity or vice versa.
- Additionally it is unclear whether tarsometatarsal instability drives hallux valgus or vice versa. Multiple studies have shown correction of HV with concurrent tarsometatarsal instability can restore sagittal stability without the need for a lapidus(33-35).

- There is a paucity of longitudinal cohort studies that observe the development of hallux valgus over time and those that have been published are limited in terms of their generalisability (e.g. teenage ballet dancers in Japan) or methodology (e.g. lack of objective assessment or radiographs)(36, 37).

Summary

- The aetiology of hallux valgus is multifactorial but commonly involves heavy loads being transmitted through a relatively unsupported first ray. Stability depends heavily on alignment and once that alignment is disrupted the ray becomes unstable. Progression in the deformity is due to eccentric pull of the extensor tendons but this is a relatively slow progress.
- Morphology of the metatarsal itself such as a rounded head, long metatarsal length and number of proximal facets may contribute. Any factor that increases the ground reaction force of the first metatarsal head is likely to contribute including pes planus deformity and hindfoot eversion. Footwear may play a major role however this is difficult to study with robust methodology.

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1.2. MIS for Hallux Valgus: Are We There Yet? *Lyndon Mason*

MIS Evidence, Acceptance and Practice

- There has been a substantial increase in published evidence supporting the role of minimally invasive techniques in hallux valgus surgery in recent years. Prior to 2020 there were 161 pubmed indexed papers relating to MIS hallux valgus surgery. Since 2021 a further 268 articles have been published reflecting a significant uplift in MIS understanding and interest.
- In 2010 MIS surgery for hallux valgus was not recommended by NICE other than in specific research contexts due to a lack of clinical evidence supporting its efficacy and safety profile. This changed in 2024 with NICE guidance recognising MIS techniques as a valid surgical option with standard arrangements in place for clinical governance, consent and audit. Part of this recommendation includes the use of national registries to maintain and build the MIS evidence base.

Evolution of Techniques

- MIS techniques have varied considerably throughout its evolution(1,2).
  The initial first and second generation techniques used minimal fixation consisting of either no fixation at all or the use of temporary k-wires.
  The consequences of this were reported loss of correction and mal-alignment and associated k-wire infection risks. Examples of first generation techniques include Reverdine-Isham, Bosch and SERI.
- The third generation saw the introduction of screw fixation with specific techniques including MICA and PECA. This provided a more stable distal osteotomy and allowed for immediate weight-bearing protocols.
  Screw prominence was a notable issue with frequent need re-operation for removal, contributing to perceived higher costs.
- The fourth and current generation utilises multiplanar correction using an extra-articular transverse osteotomy. This allows for correction of pronation and rotation. The use of two screws including a bicortical screw is one of the main defining factors between third and fourth generation, providing improved rotational stability in biomechanical studies.
- Heterogeneity in osteotomy techniques remains a challenge for research, especially with cross over between third and fourth generation.
  Earlier techniques have been pooled uncritically in research with modern techniques and can potentially provide misleading conclusions.

Outcomes

- The short term outcomes of MIS techniques appear favourable in comparison to open surgery. Supportive metrics include lower early pain scores, markedly less post-operative analgesia with rare need for opioids and less post-operative swelling(3). Additional benefits include better range of motion, faster functional recovery and higher overall satisfaction in the short term. Complication rates are low and radiographic correction has been shown to be equivalent to open techniques(4,5).
- Benefits have been seen primarily in the early window following surgery with partial convergence of outcomes by three months. Further research is still indicated however as currently comparative data comes from a single non-randomised controlled trial(3). Nevertheless, any comparative study would need to be very large, with current estimates to achieve statistical power needing over 500 cases.
- Multiple RCT's and meta-analyses have evaluated long term outcomes in MIS versus open surgery, currently suggesting no significant difference in PROMs, range of movement, radiographic correction, rate of complications or overall satisfaction scores(6,8,9,10).

Complications

- Adverse outcomes are uncommon enough in MIS literature that small RCT's have been underpowered. Older MIS fixation methods were seen to create hardware-specific reoperation problems, namely screw removal. Modern techniques may improve early wound outcomes but this does not constitute proof of fewer major complications. In research going forward complication endpoints need large, multicentre datasets to be of value and use of complication classifications which incorporate even minor complications.
- Modern MIS proficiency has been reported at 21-46 cases indicating a steep learning curve. This highlights the potential need for specific surgical training for MIS techniques to minimise complications.
- Radiological recurrence has been reported in 7.7% of cases with the PECA technique at a mean follow-up of 66.8 months(11). Recurrence using MIS techniques has been associated with inability to passively reduce the deformity prior to surgery(12).

Cost-Effectiveness

- Cost-effectiveness has been a contentious issue within MIS hallux valgus surgery, particularly given the perceived increase in re-operation rates for screw removal with earlier techniques and the elevated cost of MIS implants and jigs. Despite this, contemporary estimates now indicate that both open and MIS surgery falls far below NICE willingness-to-pay thresholds with incremental cost-effectiveness ratios of £8,737 and £11,969 respectively, meaning they are both feasible in the NHS costing structure(13).

Evidence by Deformity Severity

- Stratification of outcomes based on deformity severity is a useful way of considering MIS application in practice. Current evidence suggests that for mild deformity both open and MIS distal osteotomies are likely to work well and currently there is no proof that an MIS technique improves final outcomes. Most supplied comparative evidence relates to moderate deformity showing similar functional outcomes, correction and complication profiles to open surgery. The evidence base for severe deformity requires stratification and separate trials given the heterogeneity of open procedures i.e. MICA/PECA vs scarf/akin vs lapidus/proximal osteotomy.

Hopes for the 4th Generation Technique

- Early outcome data in the 4th generation technique appear to show greater metatarsal head translation, especially in severe deformity. Pronation and rotational aspects can be better corrected and sesamoid coverage is improved. The stable fixation design maintains correction while allowing early mobilisation.

Future Research Direction

- Direct superiority of MIS over open surgery in severe deformity remains unproven. Questions such as whether sesamoid coverage correction lowers long-term recurrence is a frontier for research. Long term follow-up data is required to answer questions relating to recurrence, particularly conservation of radiographic gains at 5 to 10 years post-surgery. Knowing which patients would benefit from MIS rather than an open procedure is of key interest.

Summary

- There remains a position of equipoise with regard to MIS hallux valgus surgery, particularly regarding long term outcomes, including recurrence and re-operation rate. Short term advantages have been demonstrated however overall benefits converge with open outcomes at three months. The potential long term advantages of MIS need to be demonstrated in the scientific literature. Patient selection remains a key aspect of surgical practice and surgeon training is of paramount importance given the associated steep learning curve with MIS techniques to minimise adverse outcomes.

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1.3. Functional Hallux Limitus (FHLim) *Phil Vaughan*

- Functional hallux limitus (FHLim) is a distinct entity from hallux ridigus. In FHLim the articular cartilage is intact but there is dynamic lack of movement at the MTPJ on weight bearing with resultant difficulties in gait. The cartilage itself is normal and it is not considered secondary to degenerative processes occurring at the joint. Dananberg defined FHLim as 'load dependent failure of the first metatarsophalangeal joint'(1).

Normal Gait

- It is worth reviewing the biomechanics of the gait cycle as this is central to FHLim pathogenesis. At heel strike the hindfoot is in valgus and moves to varus after 15% of stance phase(2). The CCJ and TNJ axis are not parallel, locking the foot to allow propulsion. In the terminal stance, or pre-swing, weight is transferred to the forefoot. The MTPJ dorsiflexes as the heel lifts. The first metatarsal plantar flexes with resultant plantar fascia tightening. This is termed the Windlass mechanism of the foot which causes arch height to increase and the heel to move into varus.

The Windlass Mechanism

- A Windlass is a mechanical device that uses rotation around a cylinder to shorten or lengthen a rope of cable(3). The foot windlass is dependent on 1st MTPJ motion and an intact plantar aponeurosis. It is passive and not an intrinsic product of muscular function although muscles provide a secondary or dynamic stabilising function.

The First MTPJ

- The first MTPJ is a synovial condyloid joint with an oval head with elliptical cavity. It produces a coupled movement in that hallux dorsiflexion is dependent on plantarflexion of the metatarsal and one cannot exist without the other. The functional range of movement for normal gait is 60 degrees(4). The stability of the MTPJ depends on soft tissues in the form of capsule, collateral ligaments, FHL and EHL and intrinsic muscles as well as the bony anatomy of sesamoids, crista and the TMTJ as well as the hindfoot position.

Pathogenesis of Functional Hallucis Limitus

- FHLim is considered to be a load dependent failure of the 1st MTPJ with failure of the windlass mechanism under load. Uncoupling of the MTPJ with failure of the 1st MT head to flex and failure of the hallux to dorsiflex means that the windlass mechanism cannot activate.
- Failure of the 1st Metatarsal head to flex can be multifactorial but common causes are considered to be prior metatarsal elevation (i.e. metatarsus primus elevatus) and excessively long metatarsals. Unstable 1st TMTs and associated hallux valgus also have a role as well as forefoot pronation and weak muscular control (peroneus longus and intrinsics).
- Failure of the hallux to dorsiflex is commonly attributed to a tight plantar fascia or FHL pathology(5). The FHL is a unipennate muscle with short excursion, reliant on short, powerful contraction. It has a retro-talar pulley and travels through a short fibro-osseous tunnel, structurally similar to the A2 pulley of the hand(6). Tendon gliding through this tunnel can be restricted by a number of causes including tendonopathy, tenosynovitis and a low muscle belly(7). This in turn can restrict hallux dorsiflexion.
- Patients with FHLim compensate for a lack of MTPJ movement in various ways that can ultimately lead to other issues in the forefoot(8). These include overactivity of EHL, shifting of their weight bearing axis laterally and pronating the forefoot as well as employing early heel lift.

FHLim Presentation

- Patients with FHLim commonly present with focal pain at the 1st MTPJ due to dorsal impingement secondary to changes in the centre of rotation. They can develop overload of the 1st of less metatarsals due to compensatory shifting of their weight bearing axis with associated transverse metatarsalgia. They may also complain of posteromedial ankle pain or planovalgus and other forefoot deformities. Plantar fasciopathy is common.

Examination Features

- Features of FHLim on gait assessment include failure to dorsiflex the hallux following terminal stance, shifting of weight laterally and over recruitment of EHL. Pinch callus is a common finding(9).
- There are a number of special tests with varying specificity and sensitivity. Jack's test involves passive extension of the hallux in weight bearing with observation of the medial arch(10). This specifically evaluates the integrity of the Windlass mechanism, which if intact will elevate the medial arch.
- The Dananberg test simulates weight bearing with pressure over the plantar aspect of the metatarsal head and passive hallux dorsiflexion(11). In a positive test the hallux will be stiff with plantar pressure but should improve once the pressure is relieved, simulating the dynamic effect of weight bearing.
- Lastly a positive FHL stretch test is characterised by inability to dorsiflex the hallux with maximum passive dorsiflexion of the ankle. A positive test suggests FHLim secondary to FHL pathology(12).

Treatment of Functional Hallucis Limitus

- Load management is a core part of non-operative management through diet and exercise. Orthoses also have a key role in off-loading the 1st MTPJ and promoting plantar flexion, for example with a reverse Morton's extension. Physiotherapy has a role in managing the muscular causes of FHLim including FHL pathology. The hoover cord manoeuvre for example is a useful technique for releasing FHL in its retrotalar pulley.
- Surgical treatments can be indicated for specific anatomical causes of FHLim. Cheilectomy can be useful in cases or dorsal impingement. In cases of instability TMT fusion can be indicated and plantarising osteotomies have been used in cases of MT primus elevatus. Addressing forefoot and hindfoot deformity in an important measure. In terms of soft tissues, debridement of the FHL or surgical release can be of use and has been described through a posterior arthroscopic approach(13,14).

Conclusions

- Functional hallux limitus is a dynamic restriction of movement of the first MTPJ. It has variable aetiology but commonly is associated with 1st ray morphology or stability or as an expression of gliding restraint by the FHL. Most of the evidence base for its management comprises review articles and anatomical or normal individual studies indicating that more robust evidence is required to guide treatment. Increasing evidence is emerging implicating the role of the FHL in the cause of FHLim and support addressing FHL pathology as part of FHLim management.

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1.4. Is Great Toe Surgery Cost Effective? *Robert Clayton*

- Cost-effectiveness is more important than ever with increasing NHS funding pressures and demand for healthcare growing faster than the economy that feeds it. More than ever there is a need to demonstrate value based care.
- The NICE threshold for approving new treatments has been set at £20-30k per quality adjusted life year (QALY) since the year 2000. This is an important benchmark and helps to provide an objective impression of cost-effectiveness of forefoot surgery.
- Hallux valgus surgery is heterogeneous and complex. There are over 100 different operations recognised and each has variable costs, benefits and re-operation profiles. This represents a challenge when calculating its cost-effectiveness and justifying its cost.

Evidence Base

- The current evidence base for hallux valgus represents an ongoing challenge. A Cochrane review of surgical intervention for hallux valgus 2024 reported 25 comparative studies with 1,597 patients(1). Only one study compared surgery with no surgery whilst others compared surgical techniques. Pain scores (VAS) were shown to have improved with surgery however a key conclusion was that study methodology was generally poor with low numbers of patients. They concluded that improvement in pain following surgery needs to be balanced against potential pitfalls and complications including revision surgery, infection and hardware prominence, all of which contribute substantially to costs.
- However, the absence of evidence of benefit does not equate to evidence of absence of benefit. There remains a continued need to provide quality evidence in support of surgery.

Costs and Variability

- Current NHS tariffs vary from £2-4k for forefoot surgery overall and £4-5k for metatarsophalangeal joint fusion. In the private sector there is generally higher overall cost and variability, for example hallux valgus and hallux rigidus surgery ranges from £3-9k.
- Costs vary widely due a number of factors including duration of stay, implant choice, theatre time, radiographer and image intensifier usage and procedure type. Scarf and chevron osteotomies are generally much cheaper than a lapidus or MIS procedure for hallux valgus which is largely explained by differences in equipment cost and surgical time. Variability in costs represents a real challenge in estimating overall cost-effectiveness.
- A previous study from Molloy et al (2020) noted the difficulties in calculating cost-effectiveness in hallux valgus surgery given heterogeneity of techniques and commented on the higher cost of MIS surgery(2).
- A recent review of BOFAS registry data from 1,119 patients undergoing MTPJ fusion demonstrated large improvements in PROMS at 1 year including EQ-5D and MOX-FQ and an overall Incremental cost-effectiveness ratio (ICER) of £1,410/QALY(3). This falls far below the NICE threshold of £20-30k, supporting ongoing commission of fusion for hallux rigidus.
- Despite this, commissioning for hallux rigidus surgery is currently under threat and in 2025 funding was withdrawn for MTPJ fusion in NHS Hampshire on the justification of ‘limited clinical effectiveness’. As a consequence patients were removed from waiting lists and rebooked into consultant clinics.
- A similar study is underway assessing cost-effectiveness of hallux valgus surgery using BOFAS registry data with provisional data suggesting ICER’s of £8,737/QALY for open surgery and £11,969/QALY for MIS. MIS surgery is considered to be more expensive on the basis of higher implant and jig costs, use of single use consumables such as burrs and blades and longer theatre time and image intensifier use. However, this is a rapidly evolving field and cost-efficiency is likely to drive further developments. For example, reducing re-operation rates for prominent screws or deformity recurrence is likely to have made a substantial difference in overall costs.

How Can We Collect Better Data to Inform Cost-Effectiveness Analysis?

- The use of the BOFAS registry allows for streamlined, centralised data pooling and provides standardised PROMS data linked to surgical procedures. Innovations such as printable QR codes have reduced barriers to engagement. Registry data is a powerful tool in providing a robust evidence base for cost-effectiveness but currently it does not record costs effectively including implant costs and theatre duration.

Conclusions

- First ray surgery is cost-effective if the indication for surgery is correct and reliable techniques are being used appropriately. Cost-effectiveness is highly dependent on low recurrence and re-operation rates. Over engineered and expensive constructs coupled with poor patient selection is likely to have a detrimental effect on overall cost-effectiveness. Providing a robust collaborative evidence base for cost-effectiveness is essential in justifying commissioning and ensuring that patients receive effective treatment for debilitating forefoot conditions.

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Consensus Questions

1. Does 1st TMTJ instability (laxity) influence your surgical strategy for HV?
   a. Yes 10 (50%)
   b. No 10 (50%)
2. Should MIS 1st Ray surgery still be considered an experimental treatment?
   a. Yes 0
   b. No 20 (100%)
3. Should MIS 1st Ray be considered standard of care for HV correction?
   a. Yes 0
   b. No 20 (100%)
4. Does MIS 1st ray surgery for HA give better short term results than open?
   a. Yes 9 (45%)
   b. No 2 (10%)
   c. Not Proven 8 (40%)
   d. Abstained 1 (5%)
5. Does MIS 1st ray surgery for HA give better long term results than open?
   a. Yes 0
   b. No 5 (25%)
   c. Not Proven 15 (75%)
6. Can we justify the extra cost of MIS HV surgery with comparison to open in NHS?
   a. Yes 4 (20%)
   b. No 10 (50%)
   c. Uncertain/Not Proven 6 (30%)
7. Does 1st MTPJ fusion surgery justify its cost in the NHS?
   a. Yes 20 (100%)
   b. No 0
8. Does open HV correction surgery justify its cost in the NHS?
   a. Yes 20 (100%)
   b. No 0

Session 2: The Lesser Toes

Chaired by Tim Williams

2.1. Implants versus K-Wires for Lesser Toe PIPJ Fusion

Andrew Kelly

K-Wire Outcomes: The Baseline Comparator

Proximal interphalangeal joint (PIPJ) arthrodesis is a cornerstone of claw toe and hammer toe correction. Traditionally, K-wires have been the standard of care and every proprietary intramedullary fixation implant that has since been marketed is, in effect, competing against it. This chapter reviews the evidence comparing the newer devices with K-wire fixation.

The established benchmark for PIPJ fixation comes from two large series using K-wires(1):

At an average follow up of 61 months:

- 92% pain relief
- 81% achieved joint fusion, fibrous union in the remaining 19%
- 84% patient satisfaction[1]

K-Wire Fixation: Baseline Outcomes (PIPJ Fusion)

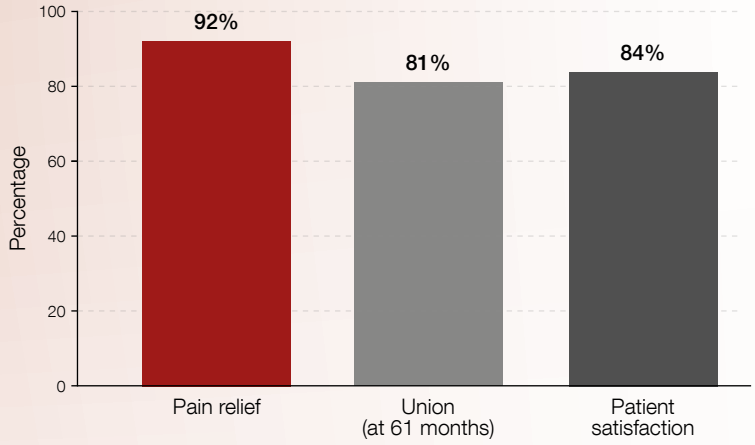


Figure 1.1 - K-wire fixation baseline outcomes for lesser toe PIPJ fusion.

Recognised limitations of K-wire fixation include:

- Patient nuisance of protruding wire
- Infection risk
- Limited rotational stability from a smooth wire, relying on the interference fit
- Migration - both extrusion and retrograde
- Distal interphalangeal joint (DIPJ) violation
- Tendency to hold the toe excessively straight failing to match the resting cascade of the toes
- Risk of breakage if the wire crosses the metatarsophalangeal joint (MTPJ)

Implant Options

Available intramedullary implants differ across four properties:

- **Material:** metal (predominantly titanium), allograft, or PEEK composite
- **Fixation:** push-fit, screw-fit, or combined
- **Construction:** one-piece or two-piece
- Angled or straight

Biomechanical data comparing implants and K-wires in the peer-reviewed literature are limited. The available data address stiffness and failure load; K-wires fail by bending, whereas implants fail by pull-out or cortical fracture.

Evidence Review 1: Comparative Synthesis (5 Studies, 4 Implants, 544 Toes)[2]

A 2020 systematic review by Wei et al. evaluated 5 studies of evidence level I,II, and III. One study was a randomised controlled trial while the other four were case-controlled studies. 4 different implants were studied against K-Wires for the following outcomes:

Union

- **1 study:** no difference between implant and K-wire
- **4 studies:** implant union rate greater than K-wire

Foot Function

- Reported in 2/5 studies (FFI and Bristol Foot Score/FFI and SF-36)
- No significant difference from K-wire

Patient Satisfaction

- Reported in 3/5 studies
- **1 study:** showed no difference in satisfaction between K Wires and implants
- **2 studies:** implants had better patient satisfaction; only one of these reported statistical significance

Pain

- Reported in 4/5 studies
- Measured by VAS (Visual Analog Score) or FFI (Foot Function Index)
- No significant difference in any study

Complications

- 3/5 studies: no significant difference
- **1 study:** no significant complications in the implant group (Angirasa et al)[3]
- **1 study:** more complications in the K-wire group (Richman et al):[4]

Implants Vs K-Wires Wei et al 5 Studies, 4 Implants, 544 Toes

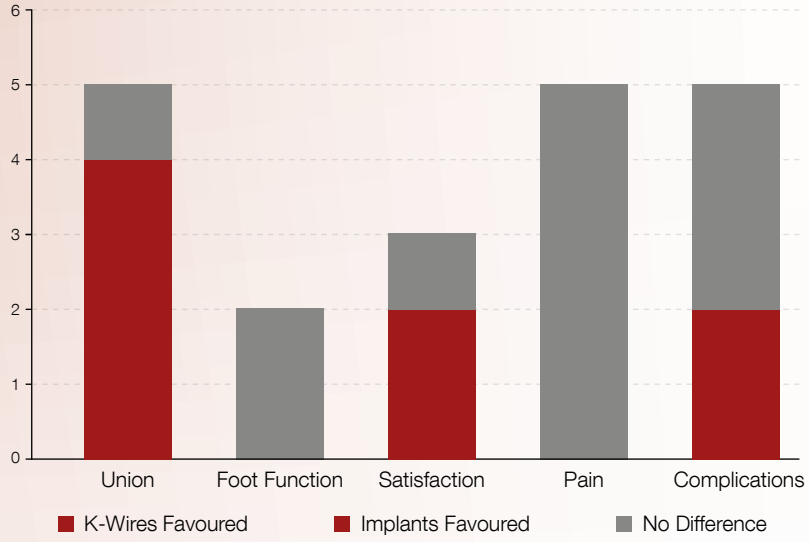


Figure 1.2 - Comparative synthesis of 5 studies (4 implants, 544 toes): number of studies favouring implant, showing no difference, or favouring K-wires across each outcome domain.

Conclusion

Based on the findings of this systematic review, **newer internal implants demonstrate a superior fusion rate compared to traditional K-wires when performing PIPJ arthrodesis for hammertoe correction.** Despite this improved bone union, the modern devices may not yield significantly better clinical outcomes regarding pain reduction, patient satisfaction, overall foot function, or the frequency of complications.

Consequently, it is necessary to carefully evaluate whether the proposed benefits of these novel implants justify their substantially greater financial cost relative to standard K-wires.

Evidence Review 2: PROSPERO-Registered Systematic Review (12 Studies, 12 Implants, 1,118 Toes)[5]

A PRISMA-compliant, PROSPERO-registered systematic review conducted by Arumugam et al in 2025, expanded the evidence base:

- 12 studies, Level I, II, and III
- 12 different implants; 1,118 toes
- Study design: 8/12 case series; 3/12 case-control studies; 1/12 prospective RCT
- **All studies rated as critical or high risk of bias**

Union

- 11/12 studies reported fusion rates of 22.2–96%
- Assessed at 3–24 months post-operatively
- 4 studies showed implant union rate greater than K-wire; pooled $p < 0.05$

Foot Function

- Improvement reported in 7/12 studies; variety of outcome instruments used
- Only 1 study reached significance
- K-wire comparison not consistently reported

Pain

- Reported in 6/12 studies; variety of instruments; all showed improvement from baseline
- None reported statistical significance
- 3 studies compared 4 implants directly to K-wire; 3 out of 4 implants mildly better with implant; none statistically significant

Satisfaction

- 7/12 studies reported improvement
- 1 study showed implant superior to K-wire (same study cited in the earlier synthesis)

Complications

- Implant breakage, cortical fracture, deformity recurrence, infection and floating toe all reported

Conclusion

“A definitive judgement on the best implant for proximal interphalangeal joint arthrodesis in hammer or claw toe correction is currently unobtainable.”

Summary: The Two Systematic Reviews Compared

Feature	Wei et al	Arumugam et al
Year	2016	2025
Studies	5 (Level 1–3)	12 (Level 1–3)
Implants assessed	4	12
Toes	544	1,118
Study design	1 Randomised Controlled Trial 4 Case Control Studies	1 Randomised Controlled Trial 3 Case Control Studies 8 case series
Risk of bias	Not specified	All critical/high
Union vs K-wire	4/5 favoured implant; 1/4 significant 1/5 no difference	4 favoured implant; pooled $p < 0.05$
Foot function vs K-wire	No significant difference	K Wire Comparison not reported
Pain vs K-wire	No significant difference	None significant (3 out of 4 mildly better)
Satisfaction vs K-wire	2/3 favoured implant; 1 significant	1 study favoured implant (same study was also cited by Wei et al)
Overall conclusion	Promising union; no advantage in pain, satisfaction, function or complications	Best implant choice "currently unobtainable"

Revision

Revision after failed implant fixation presents particular challenges. Unlike K-wire revision, removal of integrated intramedullary implants may be technically demanding and risks cortical fracture.

Cost Comparison

Direct cost comparison of fixation options:

- Single K-wire: £9.49
- 2-0 Vicryl suture: £2.85
- Average cost of implant from 2 different companies were £303 and £311

Fixation Cost Comparison: K-Wire vs Intramedullary Implants

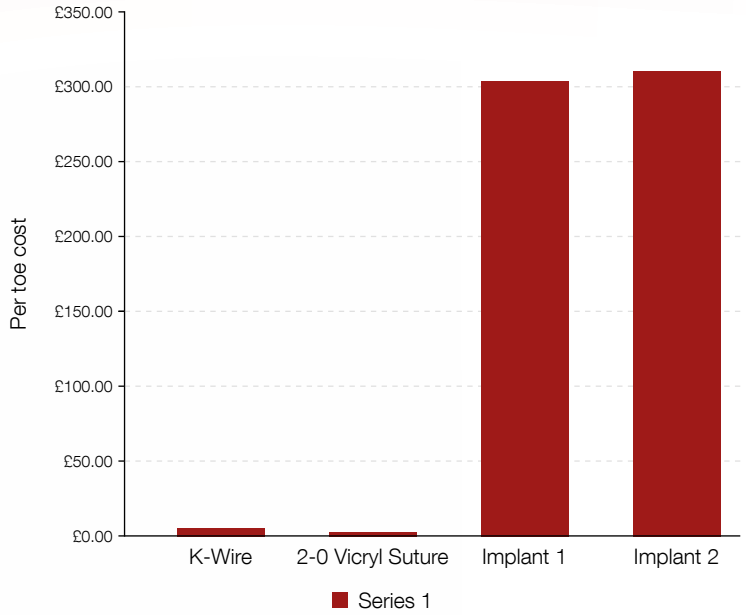


Figure 1.3 - Per-toe consumable cost: K-wire fixation versus intramedullary implants.

Summary

K-wire fixation remains the benchmark for lesser toe PIPJ arthrodesis, giving good long-term pain relief and satisfaction despite a fibrous-union rate and hardware-related nuisances such as protrusion, infection and migration. Two systematic reviews (Wei 2020; Arumugam 2025) show that modern intramedullary implants achieve higher bony fusion rates but no consistent advantage in pain, function, satisfaction or complications, while substantially costing more than a K-wire. On current evidence no single implant can be recommended as best, and the clinical case for routine implant use over K-wires is not yet made.

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2.2. Plantar Plate: Anatomy, Function and Management

Tim Williams

Plantar plate understanding has moved, over little more than a decade, from an obscure structure to one that may be more important than was appreciated

Anatomy

The plantar plate is a trapezoidal fibrocartilaginous structure with the following dimensions and composition:

- 20mm long
- 9–11mm wide
- 3mm thick
- Predominantly Type 1 collagen

Its attachments are the key to its function:

- A firm distal attachment to the base of the proximal phalanx
- A more compliant proximal attachment to the metatarsal neck containing important blood supply
- Integration with the collateral and accessory collateral ligaments medially and laterally
- The distal transverse intermetatarsal ligament (a transverse "tie-bar")
- The plantar fascia (a longitudinal "tie-bar")
- Slips of the lumbrical and plantar interosseous muscles

Function

The plantar plate is a static and dynamic stabiliser - a tether - that maintains congruence of the metatarsophalangeal joint. Rather than acting as a fixed hinge, the joint exhibits rolling and gliding so that its instantaneous centre of rotation shifts throughout movement; the tether maintains a constant functional linkage between the strong distal (phalangeal) and the more compliant proximal (metatarsal) attachments, and adapts as the joint's effective axis moves, so that alignment and contact are preserved even as the pivot point shifts.

Because each lesser toe plantar plate is attached to the plantar fascia, it participates in the windlass mechanism as a longitudinal “tie-bar”. While the hallux plantar plate is the most important contributor, all the plantar plates work in synchrony as part of the windlass mechanism.

The lesser plantar plates are interconnected together and with the hallux through the distal transverse intermetatarsal ligament, like the horses pulling a carriage, where there would be a single rein in the handler’s hands, but they are all connected to pull the carriage. This analogy can be applied to the metatarsal heads and plantar plates where they are all contributing to the load transmission and windlass mechanism. This connection serves to keep the toes stable and prevent splaying of the metatarsal heads apart.

This can explain the metatarsalgia in the lesser toes that develops secondary to hallux valgus, where the first metatarsal head drift away from the other metatarsal heads disrupting this stable connection, and creating slack in the first ray windlass, leading to a compensatory increase in the forces transmitted through the lesser toes’ windlass and increasing pressure transmitted through the lesser metatarsal heads.

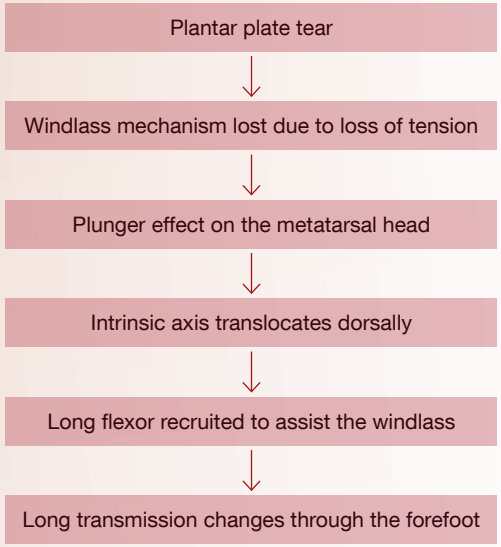
This windlass mechanism also this serves to protect the plantar skin under the metatarsal heads during gait; as the toe dorsiflexes over the metatarsal head, the working length of the plantar fascia increases and tension rises, this makes the plantar plate tauter under the metatarsal head, providing a suspensory mechanism that takes off some of the pressure on the plantar skin.

Pathomechanics of Plantar Plate Tears; A framework for dysfunction: windlass mechanism and Wolff's law

Attenuation or tearing of the plantar plate produces a mechanical cascade:

- Plantar plate tear
- Loss of the windlass mechanism due to the loss of tension
- Plunger effect on the metatarsal head
- Translocation of the intrinsic muscle axis dorsally
- Recruitment of the long flexor to assist the windlass
- Change in the load transmission patterns through the foot

Sequence of events after plantar plate tear



This sequence of events contributes to the understanding of various pathologies seen in the forefoot which might be linked to plantar plate incompetence:

- **Claw toe deformity and metatarsal overload:**
  - Due to the intrinsic axis translocation dorsally and the plunger effect of the metatarsal head.
- **Plantar callus formation:**
  - Due to the plunger effect of the metatarsal head and increased pressure on the plantar skin under the metatarsal head.
- **Stress fractures, Freiburg disease and TMT Arthritis:**
  - **Wolff's law** can be utilised in theories that hypothesise that plantar plate tears are contributory to the pathophysiology of these pathologies.
  - As the plantar plate becomes incompetent, **load shifts more proximally to the metatarsal shaft and TMT joints** which can lead to:

1. Cortical thickening and sclerosis of the metatarsal shaft → **stress fractures** if the remodelling cannot keep up with the rate of increased load.
2. Resorption and osteopenia of the metatarsal head combined with increased shear on the metatarsal heads cartilage due to incongruence of the MTP joint → **Freiburg's disease.**
3. Increased shear and loading at the level of the TMT joints → **TMT arthritis**

- **Morton's Neuroma:**
  - A plantar plate tear in the 3rd or 4th toes, may be contributory to the bursitis and secondary irritation of the interdigital nerves.

Clinical Presentation and Assessment

Key examination findings:

- Toe elevation and splaying
- Positive Lachman's test (dorsal drawer)
- Paper grip test
- Thumb roll test
- Comparison with the contralateral foot

Conservative Management

Toe Taping [2,3,4]

Acute PPT: Good evidence (Level III).

Aim: hold the plantar plate at its original length whilst healing.

Chronic PPT: Holds the toe while in use but has no additive effect to reverse the condition.

Cortisone Injection[5,6,7]

Acute PPT: No evidence; not appropriate for an acute tear.

Chronic PPT: Cautionary evidence. Provides temporary pain improvement but carries risk of worsening instability due to the loss of the protective pain sensation.

Metatarsal Dome Orthosis [3,4,5]

Potentially contributes to symptoms relief by tensioning the plantar fascia and causing secondary congruity of the MTP joint.

Acute PPT: No clinical evidence for isolated orthotic treatment, but almost always part of a combined intervention with toe tapping;

- When combined with toe taping, 50–70% improvement reported (Kinter 2020).[5]

Chronic PPT: Poor clinical evidence; always used as part of a broader conservative strategy to manage pain.

Overall Conservative Strategy

Acute PPT: No strong clinical evidence; 50–70% can improve with combined intervention.

Recommended approach: tape as soon as possible, rigid-soled shoe or sandal (carbon foot plate if available), rest, and identification and treatment of the underlying cause.

Chronic PPT: No strong clinical evidence. Conservative measures form a pain management strategy: memory foam, toe tape, podiatry/chiropody, and treatment of the underlying cause.

Surgical Management

Acute Traumatic Plantar Plate Tear

Open repair is the primary intervention. Approach options:

- Dorsal approach (with or without Weil osteotomy)
- Plantar direct repair

The evidence base is Level 4 only. Most evidence is extrapolated from chronic studies, supporting repair after failed conservative management.[8]

Chronic Claw Toe with MTPJ Involvement

A wide range of procedures is described:

- Weil osteotomy
- Stainsby procedure
- Girdlestone-Taylor transfer
- McGlamry procedure
- Hoffmann, Clayton, Lelièvre, Kelikian procedures
- Plantar plate repair (with or without concomitant procedures)

The underlying cause should be identified and be part of any surgical treatment plan.

Dorsal versus Plantar Approach

Dorsal approach (predominantly used by orthopaedic surgeons):

- Allows PIPJ arthroplasty or fusion
- Weil osteotomy for shortening, return to length, or even lengthening depending on cause
- Risk of scar and neurovascular injury

Plantar approach (predominantly podiatric surgeons; growing T&O interest):

- No change to metatarsal parabola
- Concern about plantar scar is probably overstated
- Cannot adjust metatarsal length
- Most appropriate for acute-traumatic tears
- Increasing relevance as earlier surgical intervention is considered

Systematic Review Evidence

A 2022 systematic review of plantar plate repair by MacMahon et al:[9]

Findings:

- Studies uniformly report pain and functional improvement
- Evidence quality is low
- No randomised trials
- Significant heterogeneity
- Concomitant Weil osteotomy is common
- Impossible to determine whether repair itself is superior to tendon transfer or osteotomy alone
- Level III–IV evidence overall

Surgical Technical Tips for the Dorsal Approach presented

- Avoid the proximal plantar release - preserve blood supply and any tension
- Avoid the second elevating cut - further de-tensions the repair
- Consider - Tie the plantar plate first, then restore the metatarsal head to its length where toe sits with resting plantigrade position

Addressing the Underlying Cause

The slides emphasise that treatment must address the cause of the plantar plate tear, not only the tear itself:

- **First ray pathology (hallux valgus or hallux rigidus):**
  - correct the 1st ray deformity and restore metatarsal length and the quadriga effect to re-tension the windlass mechanism
- **Tight calf/forefoot overload:**
  - consider medial gastrocnemius recession (Strayer), and second metatarsal shortening if long
- **Elevated first ray:** shorten the metatarsal respecting the Maestro metatarsal parabola if not addressing 1st ray

Summary

- The plantar plate is a trapezoidal fibrocartilaginous stabiliser of the lesser MTPJ and a key element of the windlass mechanism; its attenuation or tearing underlies claw-toe deformity, metatarsal overload and several related forefoot pathologies. The plantar plate may be more biomechanically important than previously appreciated
- Conservative care-taping, metatarsal orthoses and activity modification - helps acute tears but rarely reverses chronic ones, and cortisone injection risks worsening instability
- Surgical repair (dorsal or plantar approach) rests on low-level evidence
- Dorsal approach allows metatarsal length adjustment; plantar approach may represent the future for acute cases
- Concomitant surgery addressing the cause is essential

Key Unresolved Questions

- Should plantar plate assessment and repair form part of every Weil's osteotomy?
- Is the apparent benefit of repair simply increased scar tissue formation?

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2.3. Morton's Neuroma

Tim Clough

Diagnosis

A Morton's Neuroma is an interdigital webspace lesion, most often of the third webspace and occasionally the second webspace.

The interdigital (Morton's) neuroma is a common cause of forefoot pain, and its existence as a discrete clinical entity is not in doubt.

The difficulty is that a great deal of forefoot metatarsalgia is labelled as "Morton's neuroma" when the pain in fact arises elsewhere.

Symptoms include:

- Localised forefoot pain/burning - usually referred to the third or fourth toe
- Cramp in toes
- Palpable or audible click
- 'Stone in shoe' sensation or sensation of "walking on a pebble"
- Recurrent callosities on the sole of the foot (very rarely attributable to a true neuroma)

CONSISTENT with neuroma

- Localised webspace tenderness
- Positive Mulder's click
- Toes usually straight
- Burning/click/numb toes

Suggests a MIMIC (not neuroma)

- "Walking on a pebble"/stone-in-shoe
- Pain over the MT head (overload)
- Plantar-plate tear/MTPJ instability
- Prominent MT head, tight calves

Assessment

The diagnosis is clinical. Examination should localise tenderness to the interdigital space and reproduce a Mulder's click on mediolateral compression of the forefoot. The neuroma is a diagnosis of precise localisation to the webspace, not of the forefoot in general.

The metatarsophalangeal joint and metatarsal head should be examined separately - pain arising through the joint or over the head points away from a neuroma; in a true neuroma the joint is not particularly irritable, and the toes are usually straight.

Achilles/gastrocnemius tightness should also be examined, to rule out forefoot overload secondary to tight Triceps surae.

A general examination, including neurology and the spine, protective sensation, the vascular status and the proximal limb.

Investigations

- **Weight-bearing X-rays:**
  - Easy to obtain, and mainly used to exclude periarticular erosions or an inflammatory arthropathy rather than to demonstrate the neuroma itself.
- **Ultrasound:**
  - Regarded by many as a reasonable first-line test, but heavily operator-dependent.
- **MRI:**
  - The advantage is that an MRI scan will also identify the alternative diagnoses that so often masquerade as a neuroma.

Conservative Management

Footwear and Orthoses

- Wide shoes
- Insoles

Steroid Injection

45 feet; 45-52% success at 1 year; 31% required subsequent surgery.[1]

Alcohol Injection

45 patients; 5-year follow-up; 29% success rate; 35.6% required surgery.[2]

87 treatments in 75 patients; 14.3 months follow-up; median VAS from 8 to 4 pre and post procedure; 32% complete resolution of pain; 20% required surgery.[3]

Cryotherapy

15/20 patients showed a positive response (one series).[4]

Surgical Management

Two key series which would be useful to quote for an informed surgical consent:

- 111 feet; 6-month follow-up; 78.8% good or excellent, 11% indifferent, 10.1% poor or very poor[5]
- 41 patients; 7.4-year follow-up; 76% very good; 15% good, 2% satisfactory, 7% poor; VAS from 7 to 1.4[6]

The second series identified predictors of best outcome:

- Single neuroma
- Size > 3mm
- Symptom duration < 12 months

Non-Morton's Metatarsalgia

Causes of generalised metatarsalgia that should not be treated as Morton's neuroma:

- Prominent metatarsal heads
- Plantar plate tear
- MTPJ instability
- Tight calves

Summary

Morton's neuroma is a discrete interdigital web-space lesion, usually of the third space, and is over-diagnosed when forefoot metatarsalgia in fact arises elsewhere.

The diagnosis is clinical, with imaging (ultrasound or MRI) used mainly to confirm precise localisation and exclude mimics.

Conservative options - footwear, orthoses and steroid, alcohol or cryotherapy injections - give modest and often temporary relief with high subsequent surgery rates, whereas surgical excision yields good-to-excellent outcomes in most patients.

The best results follow a single, larger neuroma treated after a shorter symptom duration.

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2.4. Freiberg's Disease

Jane Madeley

Historical Context

- **Albert Freiberg (1914)** - an American orthopaedic surgeon, described it in a paper[1] recalling six cases (two women approaching middle age and four adolescents; three had loose bodies, one requiring surgery, while the others settled non-operatively at about six weeks). He initially favoured a traumatic mechanism, perhaps related to metatarsal length, but later conceded that trauma might not be the dominant factor. He described an infraction-an undisplaced or incomplete fracture-rather than an infarction, which is tissue death from loss of blood supply; the distinction has coloured the aetiological debate ever since.
- **Alban Köhler (1915)**[2] - the German radiologist, described a flattening or squashing of the second metatarsal head, with an infraction-like intervening space of 1-2mm in fresher cases and a uniform broadening of the distal metatarsal. He considered trauma present in only about 10% of cases and wondered about a vascular cause. The condition he described (historically "Köhler's second disease") is what we now call Freiberg's, and his contribution was acknowledged by Freiberg in a later (1926) paper.

Pathology and Aetiology

Freiberg's disease is an osteonecrosis of a lesser metatarsal head, most often the second, characterised by flattening and eventual collapse of the head with secondary degenerative change.

The cause is multifactorial and incompletely settled. Implicated factors include:

- Microtrauma
- Vascular factors - studies of metatarsal-head vascularity show variation in the contribution of the plantar and dorsal supply
- Systemic disease - the process appears more frequent in systemic inflammatory conditions such as lupus
- A possible genetic or familial component
- A short first metatarsal or long second metatarsal, increasing load on the second metatarsal
- Repetitive compressive stress such as running and dancing, which exacerbates the condition

Epidemiology

Rehm et al.[3], in 2025, published a comprehensive literature review of all PubMed publications mentioning Freiberg's disease, plus non-PubMed publications referenced therein (208 publications total):

- Estimated incidence: 1 in 2,833 live births
- 1,121 patients; 1,175 metatarsals; 4 feet with more than one metatarsal affected
- A female preponderance (780 female, 179 male, 162 unrecorded) - **it is the fourth most common osteochondritis and the only one with a female preponderance**
- The second metatarsal overwhelmingly the most frequently affected
- Most patients presenting at the higher Smillie stages, consistent with the disease being asymptomatic until collapse begins
- Surgery performed in 939 cases, with 48 different procedures described - the dorsal closing-wedge metatarsal osteotomy (DCWMO) most frequent, followed by osteochondral autograft transfer (OAT), a modified Weil osteotomy and the Smillie procedure

Freiberg's Disease: Gender Distribution (n = 1,121 patients; Rehm et al. 2025)

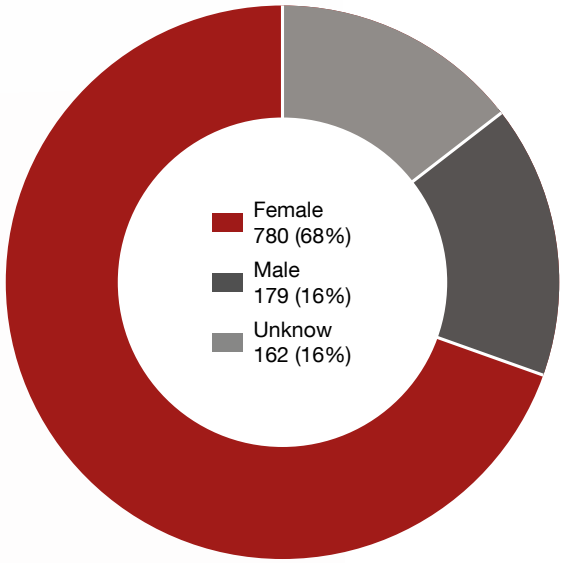


Figure 4.1 - Gender distribution in Freiberg's disease (Rehm et al. 2025, n = 1,121 patients).

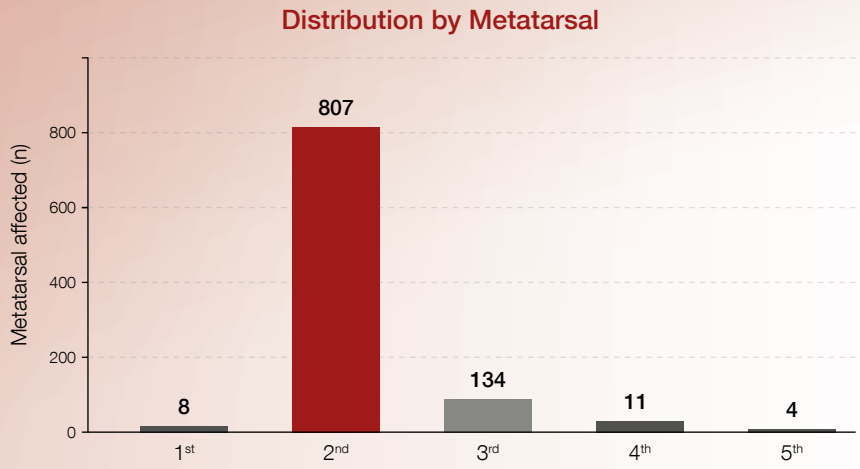


Figure 4.2 - Distribution of Frieberg's disease by affected metatarsal (Rehm et al. 2025, n = 964 patients).

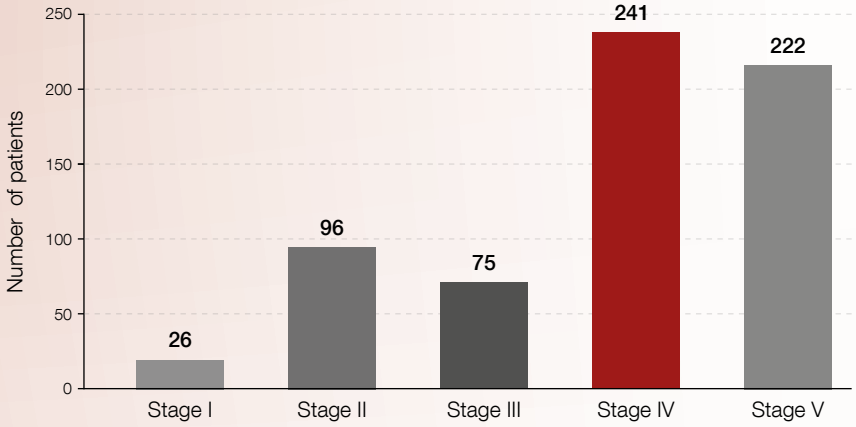


Figure 4.3 - Smillie stage at presentation across pooled literature (Rehm et al. 2025, n = 660 graded cases).

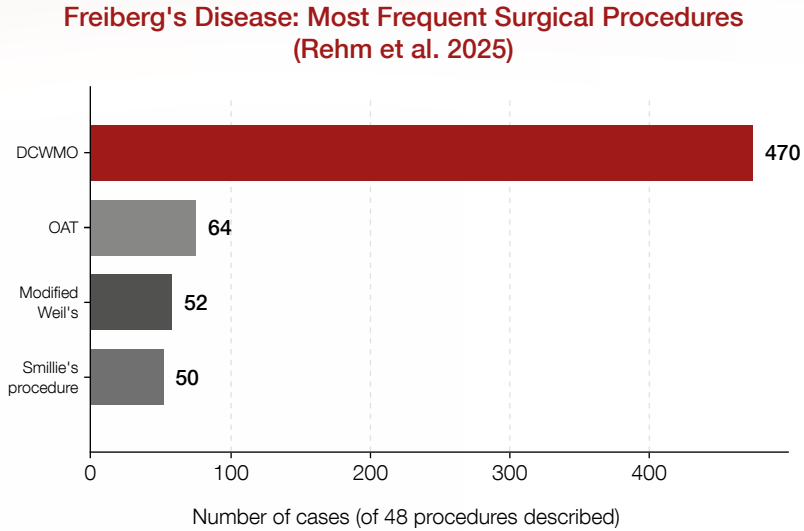


Figure 4.4 - Smillie stage at presentation across pooled literature (Rehm et al. 2025, n = 660 graded cases).

Presentation

- About 80% of patients are female, with a peak in adolescence (ages 11–17) though cases are reported up to the age of 70.
- The second metatarsal head is affected in about two-thirds and the third metatarsal head in about one-third, but all five metatarsals have been described; fewer than 10% are bilateral.
- Typical features are:
  - Pain, swelling, stiffness, crepitus, sensation of walking on a pebble
  - Often gradual onset; exacerbated by walking barefoot or in heels
  - History of recent corticosteroids identified in some cases
  - Affected toe may adopt an elevated or dorsiflexed posture
  - Later stages: coronal or sagittal plane deformity may develop
  - Gait adaptation: lateral border loading
  - Digital Lachman test: provokes symptoms and elicits instability but not specific

Evidence Landscape

The evidence base is characterised by:

- Rarity - only 1,175 cases identified in all medical literature (Rehm 2025)
- Older papers are descriptive and opinion-based
- Non-operative treatment: accepted modalities but very little studied
- One dominant classification system (Smillie)
- Multiple operative procedures with variation in post-operative protocols
- Mostly small case series (10-15 patients); few larger series (30–50 patients)
- One RCT (osteotomy vs OAT) and some comparative series
- Systematic review of surgical techniques (2021)
- Evidence-based algorithm for treatment (2023)
- Systematic review of osteotomy vs OAT (2026; 256 cases)

Imaging

Weight-bearing radiographs (three views)

The oblique views are particularly helpful as they show the head contour without overlap.

Early films may look normal or show joint-space widening and osteopenia; later, subchondral sclerosis, head flattening, central joint depression, loose bodies and degenerative change appear.

MRI - aids diagnosis in the early phase by identifying bone-marrow oedema and can demonstrate the extent of involvement. and, by imaging the whole soft-tissue field, will often reveal an alternative diagnosis if the diagnosis is not Freiberg's.

CT - helpful in staging and planning.

Bone scan - may show an early area of reduced uptake surrounded by increased activity, with later increased activity reflecting revascularisation, remodelling or arthritic change.

Differential Diagnoses

- Normal variant - 10% of the asymptomatic population have flattening of the second metatarsal head on X-ray
- Stress fracture
- Morton’s neuroma
- Plantar plate tear
- Inflammatory joint disease (gout, rheumatoid arthritis)

Smillie Classification (1967)

Developed from operative findings; applicable to X-ray or CT:

Stage	Description
I	Fissure in the epiphysis with sclerosis between cancellous surfaces
II	Absorption of cancellous tissue on the proximal side; sinking of the articular cartilage dorsally
III	Further absorption and sinking; bony projections medially and laterally; exostosis on dorsal proximal metatarsal head
IV	Articular surface sunken beyond the point of restoring normal anatomy; fractures of medial and lateral projections may occur
V	Arthrosis with flattening and deformity of the metatarsal head; cartilage retained only on the plantar surface; metatarsal shaft thickened and dense

Non-Operative Management

Goals:

Symptom relief and maintenance of a functional gait.

Most patients with Smillie Stages I - III respond well to non-operative treatment**:**

- 60% achieve significant improvement at 1-3 years. Treatment for at least 6 months may be required. (Most papers cite Helal and Gibb, 1987[13]).

Non-operative modalities:

- Activity modification
- Acute phase: cast or Velcro boot for 2-6 weeks, with gradual remobilisation once symptoms respond
- Stiff-soled shoe
- Metatarsal bar
- Anti-inflammatory analgesia
- Steroid injection (controversial)

Emerging modalities:

- Extracorporeal shockwave therapy (ECSW): report of 2 cases treated with focused SWT; promising results[4].
- Bisphosphonate therapy: intravenous zoledronate followed by weekly alendronate for a year, which eliminated symptoms and slowed the progression of avascular necrosis in a study of 18 patients with non-femoral osteonecrosis, of whom two had Freiberg's disease[5].

Operative Management

Surgery is reserved for patients whose symptoms persist despite non-operative measures. Multiple procedures have been described, chosen according to disease stage:

- Debridement, with or without removal of loose bodies;
- Debridement with core decompression or microfracture;
- Debridement with head reconstruction;
- Debridement with osteotomy;
- Debridement with interposition arthroplasty;
- Arthroplasty;
- Metatarsal-head excision (as a salvage).

The Sheffield CT classification (Hoggett et al., The Foot, 2022)[6] may guide decision-making by dividing the head on a sagittal slice into zones 1 and 2:

Disease confined to zone 1 favours debridement and osteotomy, whereas involvement of zones 1 and 2 points towards debridement with arthroplasty or interposition.

The classification showed high intra-observer and inter-observer reliability (100% and 95.8% respectively).[6]

Joint Debridement

Removal of **synovitis, loose bodies, osteophytes and delaminated cartilage.**

- 1957 → Freiberg JA; described in an instructional lecture[7]
- 1993 → Sproul et al.; 11 patients; improved symptoms; 80% range of motion restoration[8]
- 2012 → Pastides et al.; debridement with microfracture; detached cartilage sutured back over defect; 11 cases, Stages III and IV; significant improvement in pain scores; 6/11 regained normal range of motion at 6 months[9]
- 2013 → Erdil et al.; improved clinical symptoms and self-reported health status[10]

Core Decompression/Microfracture

Evidence for this technique in the femoral head, and some evidence for the talus.

Technique: drilling multiple K-wire holes via the articular surface into the necrotic area of the metatarsal head. Suitable for early-phase disease without head collapse.

Level of evidence: case reports[11,12]

Perichondral Grafting (Head Reconstruction)

Originally described by Smillie for Stage II–III disease that has failed non-operative treatment: elevation of the sunken articular surface with impaction of bone graft to restore head shape.

Helal and Gibb (1987, Foot and Ankle): 11 patients; at 3–9-year follow-up, 8 were clinically and radiologically normal; 3 had expanded metatarsal heads (1 asymptomatic; 2 had problems with high heels/running).[13]

Mutlu et al. (2023): retrospective review; metatarsal head restoration (n = 32) vs osteotomy (n = 32) in adolescents with open growth plates:[14]

- Mean AOFAS score: 89.35 (head restoration) vs 78.24 (osteotomy)
- Post-operative ROM: 56.28° (head restoration) vs 47.65° (osteotomy)
- All $p < 0.05$

AMIC (Autologous Matrix-Induced Chondrogenesis) - Chondrogide Membrane

Rajeev et al. (2023, Journal of Foot and Ankle Surgery): 10 cases; mean age 42.7 years; mean follow-up 36.4 months; dorsal approach, debridement, microfracture, cancellous bone grafting and Chondrogide membrane:[15]

- VAS improved from 47.3 to 26.4
- MOxFQ improved from 72.5 to 31.4
- Good results equivalent to other joint-preserving techniques

Osteochondral Autograft Transfer (OAT)

Indicated for larger Smillie II–IV lesions in younger, athletic patients. Donor site: ipsilateral knee (lateral femoral condyle, non-weight-bearing zone).

- 2002 → Hayashi et al.: case report with an ipsilateral knee donor[16]
- 2011 → Tsuda et al.: 3 cases in adolescent athletes; all returned to sport at 3 months; no donor-site problems[17]
- 2008 → Miyamoto et al.: 4 cases[18]
- 2016 → Miyamoto et al.: published midterm results for 16 cases; increased AOFAS score and ROM[19]
- 2017 → Ishimatsu et al.: 12 young athletes; improved Japanese Foot and Ankle Score and Halasi score; return to sport at 3.5 months; improved ROM[20]

Dorsal Closing Wedge Metatarsal Osteotomy (DCWMO)

- Indicated for Smillie Stages III and IV.
- Diseased cartilage removed; healthy plantar cartilage rotated into the joint space.
- Outcomes better with smaller areas of involvement.
- Both intra- and extra-articular variations exist.
- Risk: elevation or shortening of the metatarsal head; transfer metatarsalgia.
- Average shortening: 2mm.

Individual series:

- 1979 → 53 cases - Gauthier and Elbaz; intra-articular dorsal closing wedge[21]
- 1989 → 10 patients - Kinnard and Lirette; all improved pain and sporting activity; 2.3 mm shortening; no metatarsalgia[22]
- 1999 → 13 patients - Chao et al.; extra-articular; K-wire fixation; 4 excellent, 7 good; no complications; 2–4-year follow-up; 15° loss of ROM[23]
- 2007 → 12 cases - Lee et al. (FAI); Smillie Stages II–V; all excellent results; bioabsorbable pins[24]
- 2015 → 30 cases - Helix-Giordanino; 6.5-year follow-up; mean post-op AOFAS 83; 17 very satisfied; average shortening 2 mm[25]
- 2011 → 15 cases - Nathdwarawala et al.; average 10 weeks to union; AOFAS improved from 54 to 82; average 2.5-year follow-up[26]
- 2016 → 20 patients - Pereira et al.; 23.4-year follow-up; no complications; high satisfaction; mean AOFAS score 96.8[27]

Shortening Osteotomy

Smith et al. (1991, JBJS Br): extra-articular shortening osteotomy; 16 feet in 15 patients:[28]

- 14 had pain relief at 12 months
- Approximately 4 mm shortening required
- Alters the metatarsal parabola; toe may appear shorter
- Most patients had persistent MTPJ stiffness
- 4 feet had decreased toe flexion and inability to bring toes to the ground

Modified Weil's Osteotomy

Kooner et al. (2023, Foot): 12 feet (9 second MT, 3 third MT); 6 Grade IV, 6 Grade V; mean follow-up 5.2 years:[29]

- AOFAS improved from 48.1 to 88.9
- 92% satisfied; all united
- 1 superficial post-operative infection

DCWMO versus OAT: Comparative Studies

Three studies have directly compared DCWMO and OAT:

2019 → Georgiannos et al.: Randomised Controlled Trial; 27 cases (13 OAT vs 14 DCWMO):[30]

- Improved AOFAS scores in both groups
- Faster return to sport with OAT
- Authors propose larger surface area for healing and improved congruence as factors

2020 → Kim et al.: retrospective comparative study; 27 cases (12 OAT, 15 DCWMO):[31]

- OAT: better AOFAS scores
- DCWMO: reduced range of plantarflexion

2025 → Incesoy et al.: 16 cases (8 OAT, 8 DCWMO):[32]

- OAT yielded better Sport-FADI and Activity-FADI scores and greater plantarflexion ROM, whereas DCWMO produced a higher AOFAS-LMI score
- Sport-FADI 94.04 vs 84.75 and Activity-FADI 97 vs 92 (both favouring OAT); plantarflexion 43.13° (OAT) vs 6.88° (DCWMO); AOFAS-LMI 86.75 (DCWMO) vs 75.38 (OAT). All statistically significant

Systematic Review: DCWMO versus OAT (2026)

A systematic review conducted by Tham et al[33] in 2026 looked at 16 studies; 259 toes (62 OAT vs 197 DCWMO); 3 directly comparative studies:

Comparative study findings:

- No difference in absolute AOFAS or VAS scores, both of which improved in both groups
- OAT: significantly greater functional gain (+7.15 AOFAS points)
- OAT: greater post-operative dorsiflexion; trend to greater plantarflexion; greater gain from baseline in dorsiflexion
- DCWMO: 2.1 mm metatarsal shortening (2 studies)
- OAT: shorter return to sport (mean difference: 2 weeks to training; 3 weeks to sports)
- Complications: OAT 1% (donor-site knee pain) vs DCWMO 6% (5 stiffness, 2 joint malalignment, 2 metatarsalgia

Pooled data (all 16 studies):

Outcome	DCWMO	OAT
AOFAS - mean improvement	25.6	25.6
VAS - mean decrease	5.2	5.8
Dorsiflexion improvement	14.9°	19.6°
Plantarflexion improvement	0°	8°
Metatarsal shortening	1.76mm	-0.2mm
Complication rate	6%	1%

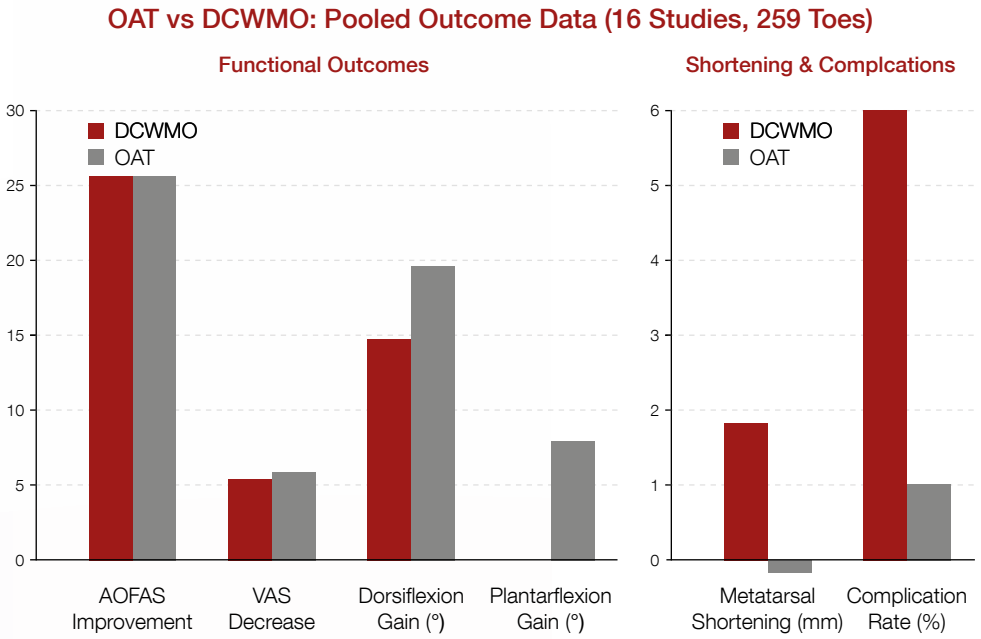


Figure 4.4 - Pooled functional, shortening and complication outcomes: OAT versus DCWMO (16 studies, 259 toes; 2026 systematic review).

Conclusions of the 2026 systematic review:

- OAT provided significantly greater functional improvement, restoration of ROM and fewer complications than DCWMO in Freiberg's disease
- OAT avoids altered biomechanics via metatarsal shortening and transfer metatarsalgia
- OAT may be the preferred joint-preserving surgical option for advanced Freiberg's disease
- Limitation: still small overall numbers; only 3 directly comparative studies[33]

Arthroplasty Options

For disease beyond the scope of joint-preserving surgery, arthroplasty options include:

- Interposition arthroplasty
- Hemiarthroplasty (e.g. HemiCAP)
- Cartiva implant
- Silastic implant
- Excision/metatarsal head resection

Complication Data: Rehm Pooled Analysis (2025)[3]

Pooled complication rates by procedure:

Procedure	Feet	Complication rate	Most common complication
Cheilectomy and microfracture	29	3.4%	Superficial infection
DCWMO via defect	284	7.4%	Transfer metatarsalgia, metalwork irritation
DCWMO extra-articular	118	3.4%	Pain, transfer metatarsalgia
DCWMO intra-articular (proximal to defect)	15	20%	AVN
Modified Weil's	52	7.7%	Toe stiffness and deformity
Extra-articular shortening osteotomy	16	62.5%	Toe stiffness and deformity
Perichondral grafting	60	3.3%	Donor-site issues
OAT	60	3.3%	Donor site
PVA Hydrogel implant	15	54%	Pain and stiffness
Silicone implant	40	7.5%	Metatarsalgia
MT head excision	6	33.3%	Pain, difficulty with footwear
Partial MT head excision	23	26%	Pain, cosmesis
Hemiphalangectomy	4	75%	Pain, difficulty with footwear

Freiberg's Disease: Pooled Complication Rates by Procedure (Rehm 2024)

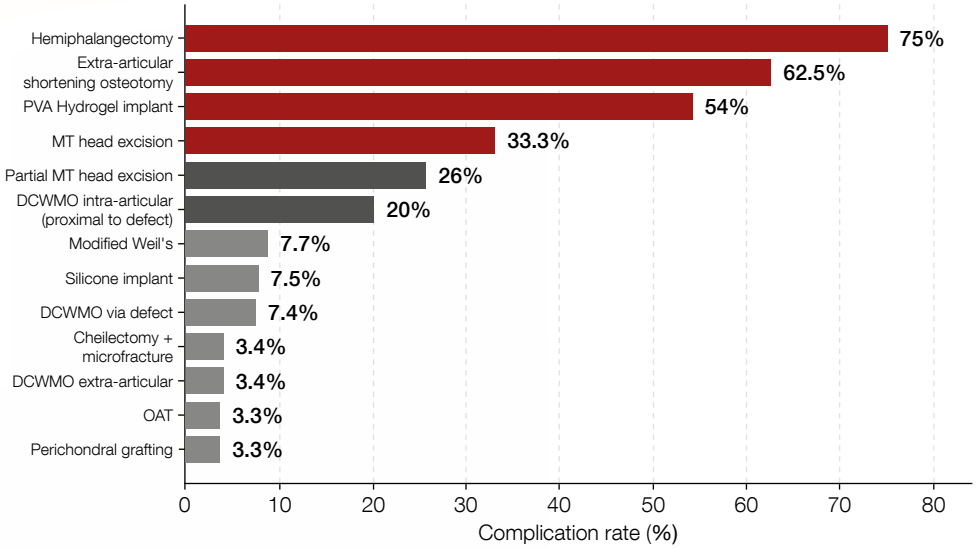


Figure 4.5 - Pooled complication rates by procedure for Freiberg's disease (Rehm 2025).

Suggested Algorithm

Yoshimura et al. (2023) proposed an algorithm based on current literature and expert opinion.

They suggested non-operative treatment as first-line, particularly for early-stage (Smillie I-II) disease; then operative management to be decided based on the Smillie stage, presence of loose bodies, synovitis, cartilage delamination or osteophytes, size of the lesion, patient age and activity level.

Stages I-II - core decompression and/or joint debridement

Stages III-IV - decision between DCWMO and OAT based on lesion size, patient age and activity level.

Stages IV-V - interposition or implant arthroplasty (implant reserved for low-demand patients and not recommended as routine treatment).

Summary

- Freiberg's disease is a rare osteonecrosis of a lesser metatarsal head-most often the second-with a marked female preponderance and a multifactorial cause.
- It is staged by the Smillie classification, and most early-stage (I–III) cases respond to non-operative treatment.
- Paucity of good-quality evidence to inform treatment guidelines
- Surgical treatment only when non-operative measures have failed
- Avoid creating a transfer lesion
- Early mobilisation to avoid stiffness
- Rare condition making prospective study difficult: multicentre registry data collection should be considered

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2.5. Osteoarthritis of the Second Metatarsophalangeal Joint

Callum Clark

Prevalence

- Roddy et al[1] published a systematic review of foot arthritis epidemiology in 2018:
  - Foot pain affects 1 in 4 people over 75 years of age
  - Minimal data in the literature compared with hand, hip and knee arthritis
  - Most studies focus on the first MTPJ or mixed lesser MTPJs
  - Prevalence of MTPJ 2-5 OA: approximately 3-5% in the 30-60-year age group (female predominance)

Causes of Second MTPJ Osteoarthritis

- End-stage Freiberg's disease
- Primary osteoarthritis that one group has termed "second-toe rigidus"[2]
- The sequelae of plantar-plate instability, where deformity (rather than the arthritis itself) is often the dominant problem;
- Inflammatory arthropathy
- Post-traumatic or post-surgical causes

"Second toe rigidus"[2]: a retrospective comparative series studying symptomatic 2nd MTPJ arthritis. Those with Freiberg's disease or a history of inflammatory arthritis, trauma, or Charcot arthropathy were excluded. 37 feet with symptomatic 2nd MTPJ arthritis vs 50 matched controls (50 feet in 34 subjects) were studied;

Found that the risk of second MTPJ OA was increased with:

- Increased second metatarsal (M2) length
- Increased second metatarsal (M2) head size

The authors interpreted the larger head as an effect (an early sign of arthritis) rather than a cause, while a long second metatarsal probably predisposes to the condition.

A grading system of 0–3 was applied.[2]

Effect on Gait

There is a significant evidence gap regarding the effect of second MTPJ restriction on gait:

- Most multi-segment foot models (including the Oxford Foot Model and Leardini model) do not track individual lesser MTPJs as discrete moving segments
- Kinematic data for the second MTPJ during gait do not exist in the peer-reviewed literature to any meaningful degree
- No dedicated gait analysis studies measure the effect of isolated second MTPJ restriction on lower limb kinematics
- Almost all published gait analysis data relate to the first MTPJ

Pedobarographic data indicate:

- The second metatarsal is the longest and carries the highest peak plantar pressure during the propulsive phase
- The second toe has a meaningful, although secondary to the first ray, role during terminal push-off

Normal range of motion of the second MTPJ:

- Published static values for lesser MTPJ dorsiflexion: approximately 35-45° compared to first MTPJ: 70-90°
- Second metatarsal head has a smaller radius of curvature and shorter lever arm than the first
- Body weight transfer during terminal stance moves medially - the hallux is the dominant lever
- The lesser toes function more as stabilisers during push-off than as primary propulsors

Conservative Management

Conservative measures are those used across forefoot conditions, with little specific literature for primary 2nd MTPJ arthritis. Evidence is strongest for the early stages of Freiberg's and for plantar-plate problems, where metatarsal domes and toe-taping have been shown to halt the progression of a progressive hammer-toe deformity once a plantar-plate rupture is identified.

Conservative measures include:

- Stiff-soled footwear
- Activity modification
- Metatarsal dome/bar orthosis (offloads the MTP joint)
- Custom orthoses
- Physiotherapy
- Corticosteroid injection

Evidence for non-operative treatment:

- Non-operative treatment is recommended first-line for Smillie Stages I–II Freiberg's disease.
- Conservative management in plantar plate pathology can halt progression but does not correct established deformity.

Surgical Management

Surgical decision-making involves:

- Joint-preserving vs joint-sacrificing surgery
- With or without deformity correction
- With or without hallux or other lesser toe surgery
- Note: pathologies are frequently grouped together in published series

Joint-Preserving Surgery: Cheilectomy versus Weil Osteotomy

A 2016 study by Kim et al[3]:

61 feet in 51 patients were retrospectively reviewed; mean follow-up of 15 months:

- Cheilectomy group (n = 36 feet): removal of dorsal osteophyte from the second MTPJ
- Weil osteotomy group (n = 25 feet): second metatarsal shortening plus osteophyte removal
- Both groups achieved significant VAS pain improvement
- Cheilectomy group had no significant change in the radiological osteoarthritis grade

- Weil osteotomy group had a significant improvement in the osteoarthritis grade
- Cheilectomy group showed a statistically higher prevalence of second MTPJ disturbance at the last follow-up[3]

Plantar Plate Repair

A systematic review in 2017 looked at plantar plate repair to address lesser MTPJ instability.

6 case series were identified with 162 patients who underwent plantar plate repair in addition to either Weil osteotomy or flexor digitorum longus transfer.

Good outcomes were reported, but heterogeneous groups, poor methodology and high bias risk.[4]

Joint-Sacrificing Surgery

Options include:

- Resection/interposition arthroplasty (metatarsal or phalangeal)
- Implant arthroplasty: hemiarthroplasty; total joint replacement; hinged implant
- Arthrodesis

Interposition arthroplasty techniques:

Interposition arthroplasties are described in small case series and reports:

- **Extensor digitorum brevis**: sectioned proximally and threaded through a drill hole in the phalangeal base as an "anchovy" joint spacer;
  - 24 patients; advanced Freiberg's Smillie stages III - V; good results at 5 years[5]
- **Periosteum and fat "rollmop":** distally based periosteum-and-fat "rollmop"
  - 25 cases; advanced Freiberg Smillie stages III-V; good results at 3.5 years; technique evolved mid-series from trans-articular K-wire to graft-to-plantar-plate suture; patients had better outcomes[6]
- **Hamstring allograft:** frozen semitendinosus tendon allograft fixed with a suture anchor into a reamed metatarsal-head concavity
  - 15 feet;, good results at 4.2 years[7]

Resection arthroplasty and Stainsby procedure:[8,9,10,11]

Predominantly reported in rheumatoid disease, deformity correction and associated first-ray surgery. Complication data from mixed series:

- Superficial wound problems: ~34%
- Toe paraesthesia: ~19%
- Floating toe risk
- All series are mixed (RA, claw toe, dislocation, arthritis)
- No comparative studies exist

Implant arthroplasty:

- Polyvinyl Alcohol Hydrogel Implant:[12,13]
  - Lesser-MTP implant series gave good early results, but a subsequent series of 14 joints for end-stage disease had complications in over a third, after which the prosthesis was withdrawn
  - 14 joints (end-stage Freiberg's or Osteochondral lesions): improved PROMs; 5 complications (AVN, revision, fracture, 2x pain) - "not without its complications"
- Hemiarthroplasty[14,15]
- Total Ceramic Arthroplasty
  - 9 patients Moje arthroplasty; 2-year follow-up: good–excellent results[16]
- Silicone Implant Arthroplasty
  - Old 1988 series; 31 implants for deformity: 37% failure or "reservations"[17]
- Three Dimensional Printed Lesser Metatarsal Replacement[18]

Arthrodesis of the lesser MTPJ:

Isolated second MTPJ arthrodesis was historically considered to be poorly tolerated by patients and was generally discouraged. These recent series, however, are all for severe, recalcitrant deformity rather than for arthritis alone, and patient-reported outcomes were good in these selected groups.

- 11 fusions for crossover hammertoe; 10/11 fused; good results; described as "an alternative to amputation"[19]
- Case report: Concomitant first and second MTPJ arthrodesis; promising result[20]
- 5 toes fused (all united): "viable surgical option for severe recalcitrant deformities"[21]

Summary

Osteoarthritis of the second MTPJ is under-studied and arises from end-stage Freiberg's disease, primary 'second-toe rigidus', the sequelae of plantar-plate instability, and inflammatory or post-traumatic causes.

Kinematic gait data specific to the joint are essentially absent.

Conservative measures mirror those used across forefoot conditions.

Joint-preserving options (cheilectomy, Weil osteotomy, plantar-plate repair) and joint-sacrificing options (interposition or implant arthroplasty, and-despite historical caution-arthrodesis for severe deformity) are all supported only by small, heterogeneous series without comparative trials.

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2.6. Cost-Effectiveness of Lesser Toe Surgery *Dessie Gibson*

Defining Cost-Effectiveness

Cost-effectiveness in the NHS context:

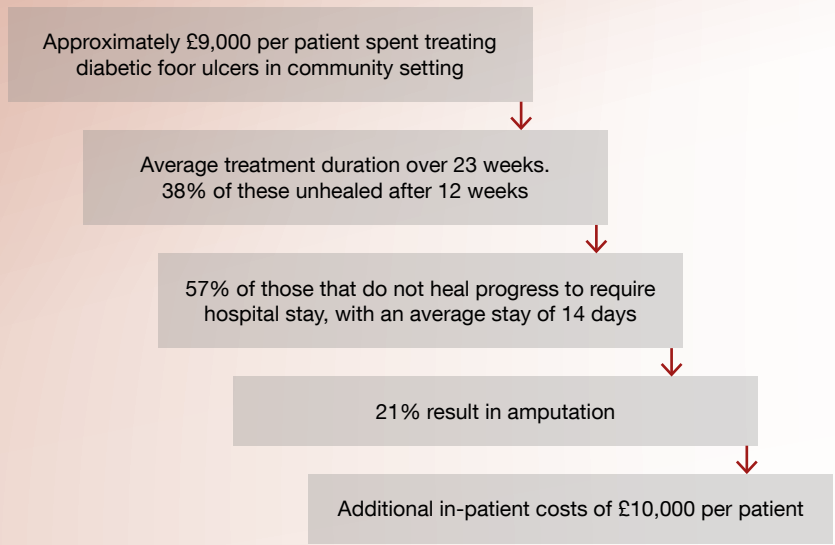
- **ICER (incremental cost-effectiveness ratio)**
  - It divides the difference in cost between two treatments by the difference in their effectiveness
  - $$\text{ICER} = \frac{\text{Cost New - Cost Standard}}{\text{Effectiveness New - Effectiveness Standard}}$$
  - **The Numerator (Cost):** The incremental cost, usually measured in currency (e.g., dollars or pounds).
  - **The Denominator (Effectiveness):** The incremental health benefit, most commonly measured in QALYs (Quality-Adjusted Life Years)
  - **QALY** factors in both the additional time a patient lives because of the treatment and the quality of life during those years.
  - The result is typically expressed as **"Cost per QALY gained"** (for example, £15,000 per QALY)
- NICE threshold: typically, £25,000 to £35,000 per Quality-Adjusted Life Year (QALY)[1]
- Key determinants: procedure cost and quality-of-life gain
- True costs are rarely known with any precision but include; surgery, implants, theatre time, follow-up and complications

Why This Question Matters

- High prevalence of hammertoe, claw toe and crossover deformities
- Growing pressure on NHS resources and waiting lists
- Need to justify surgery beyond radiographic correction
- Diabetic foot disease represents a major cost burden and resource utilisation for forefoot surgery

The Burden of Diabetic Foot Ulceration

Data from the Royal College of Podiatry CCG and STP Toolkit:



Minor Procedures in the Outpatient and Day-Case Setting

The presenter describes a model of clinic-based minor surgery applicable to both diabetic and elective patients:

Tip-of-Toe Ulcers Over a Flexible Flexed Toe

A percutaneous flexor tenotomy under local anaesthetic is quick and effective. A blunt (pink) filter needle is preferred to a sharp green needle because it is more rigid, gives more feedback and behaves more like a blade, and it can be attached to the syringe and held like a pencil for grip.

Rigid Deformities

Open PIPJ correction (excision arthroplasty or arthrodesis) as a minor day-case procedure.

- **Average direct cost at one unit (Altnagelvin, Northern Ireland):** £2,000 for minor procedures

Corrective PIP Joint Resection in the Outpatient Setting

For selected patients; PIP joint resection without K wire fixation can be carried out in the outpatient setting.

- This technique is supported by a randomised controlled trial conducted in 2016[2];
  - Patients with rigid hammertoe deformities were randomized into two groups: PIP joint (PIPJ) resection (26 patients, 39 toes) and PIPJ fusion (29 patients, 50 toes).
  - At the one-year follow-up, both surgical procedures yielded good to excellent improvements in pain and activity levels. While overall foot function and pain scores showed no significant differences between the two methods, PIPJ fusion provided a statistically significant advantage in achieving better toe alignment in the sagittal plane.

OPD Forefoot Procedures

Procedure time: 10-15 minutes. Consumable cost per procedure:

- ✓ Dressing pack
- ✓ Disposable suture set
- ✓ Disposable scalpel
- ✓ 3/0 Ethilon
- ✓ 1% lignocaine
- ✓ Syringe and 2 needles
- ✓ Dressings
- ✓ Total cost: £12.50

Current Evidence Base

- Evidence is limited compared with hip and knee arthroplasty
- Few formal economic evaluations exist
- Most studies demonstrate substantial PROM improvement after correction
- Clinical outcomes: pain reduction, improved walking tolerance, improved footwear options and patient satisfaction.
- Benefits greatest in symptomatic deformity after failed conservative care.

Cost Drivers

- Operating time and day-case efficiency
- Implant use versus K-wire fixation
- Revision surgery and complications (infection in particular)
- Post-operative resource utilisation

Implant-Based Correction

The value proposition of intramedullary implants for lesser toe correction:

- Remains uncertain
- Limited evidence of superior PROM gains over K-wire
- Potential convenience advantages of intramedullary implants
- Higher implant expenditure

Potential Economic Benefits of Surgical Correction

- Improved health-related quality of life
- Reduced podiatry and footwear modification requirements
- Possible reduction in falls risk and disability
- Return to work in selected patients

Where Cost-Effectiveness is Strongest

- Painful, fixed deformities
- Failed non-operative treatment
- Carefully selected patients with realistic expectations
- Efficient day-case pathways

Where Value is Less Certain

- Mild symptoms
- Cosmetic indications
- Complex revision cases
- High-risk patients with elevated complication rates

NHS Perspective: Key Messages

- Lesser toe surgery is likely cost-effective when meaningful PROM gains are achieved
- Better UK-specific economic studies are needed
- Routine collection of PROMs and resource-use data is essential

Summary

Cost-effectiveness in the NHS is judged by cost per QALY against a threshold of roughly £25,000–£35,000, yet formal economic evidence for lesser toe surgery is scarce. Much correction can be delivered as low-cost day-case or outpatient minor surgery (consumables around £12.50), and timely intervention may offset the very high costs of diabetic foot ulceration. Value is greatest for painful, fixed deformities failing conservative care in well-selected patients, and least certain for mild or cosmetic cases, while intramedullary implants add cost without proven PROM benefit. Better UK-specific cost-utility studies and routine PROM collection are the clear priorities.

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Discussion and Consensus Session 2

Following the presentations, an open discussion was held chaired by **Mr. Tim Williams**. Delegates participated in audience voting on key clinical questions. The consensus statements and voting results are recorded below.

Implants versus K-Wires for PIPJ Fusion

No delegate reported using toe implants on a regular basis. The group discussed hammertoe treatment approaches, including the choice of titanium versus stainless steel K-wires, implants, and interpositional techniques.

Implants versus K-wire was highlighted as showing no major clinical difference, but with substantially higher cost.

The general view was that implants are expensive and the cost does not justify their routine use. Minority situations in which an implant might be considered include metal allergy or a patient who is unwilling to accept an external wire.

Consensus Statements

1. The accepted standard for PIPJ fusion or excision arthroplasty is fixation with K-wires.
   - a. Yes 20
   - b. No 0

2. In the right environment, for selected patients (e.g. low-demand or neuropathic patients), excision arthroplasty without K-wire stabilisation is a safe and reasonable surgical option for PIPJ deformity.
   - a. Yes 20
   - b. No 0

3. In exceptional circumstances, it is acceptable to consider non-K-wire implant fixation for PIP fusion for selected cases.
   - a. Yes 17
   - b. No 2
   - c. Abstain 1

Plantar Plate Repair

Outcomes of plantar plate repair were felt to be variable, with anecdotal reports of post-operative stiffness and limited pain relief. Practice was mixed: some delegates have never performed the repair, while others reported a more routine place in their surgical practice. Acute traumatic plantar plate presentations to secondary care were discussed but considered rare.

Consensus Statements

1. There is a place for plantar plate repair as an operation.
   - a. Yes 18
   - b. No 2

2. What approach do you use for plantar plate repair?
   - a. Always dorsal 16
   - b. Always plantar 0
   - c. Occasionally plantar 2
   - d. Do not perform 2

Morton's Neuroma

The group discussed the diagnostic value of the Mulder's click and the importance of proper clinical diagnosis of Morton’s Neuroma. Intermetatarsal ligament release was noted as a useful technique when managing multiple neuromata.

Consensus Statements

1. In the NHS settings, should we routinely offer to inject Morton's neuroma with anything other than cortisone (e.g. cryotherapy, alcohol)?
   - a. Yes 0
   - b. No 19
   - c. Abstain 1

2. When undertaking a cortisone injection for Morton's neuroma, it should be done under image guidance.
   - a. Yes 9
   - b. No 8
   - c. Sometimes 2
   - d. Abstain 1

Freiberg's Disease

The group discussed concerns about bisphosphonate treatment in women of childbearing age, which is the common age group for Freiberg’s disease, with concern for potential effects on the foetus given the drug's late clearance.

Consensus Statements

1. A trial of conservative management should be the initial standard of care for all stages of Freiberg's disease.
   a. Yes 20
   b. No 0

2. In a patient who has failed conservative management with late-stage Freiberg's disease, which procedure would you consider? (participants could select more than one option)
   a. Cheilectomy and debridement of joint alone 12
   b. Weil-style osteotomy 9
   c. Osteotomy based at neck rather than a Weil's Osteotomy 8

Second MTPJ Osteoarthritis

Consensus Statements

1. What are the functional consequences of untreated 2nd MTPJ OA versus hallux rigidus?
   a. Less severe 0
   b. Same 13
   c. More severe 2
   d. Abstain 2

2. Given the prevalence of isolated 2nd MTPJ OA in the UK, is interposition arthroplasty an acceptable treatment?
   a. Yes 15
   b. No 1
   c. Abstain 2

3. Is there enough evidence to justify not recommending 2nd MTPJ implant arthroplasty for OA outside of specific lines of agreed audit?
   a. Yes 17
   b. No 0
   c. Abstain 1

4. Should 2nd MTPJ fusion be considered acceptable in OA?"
   a. Isolated ray 0
   b. Always in combination with 1st MTPJ fusion 0
   c. Don't know 18

5. Who has personal experience of lesser toe MTPJ fusion in their practice?
   a. Yes 0
   b. No 18

Cost-Effectiveness of Lesser Toe Surgery

Consensus Statements

1. Is lesser toe surgery cost-effective for painful deformity based on available evidence?
   a. Yes 18
   b. No 0

2. Can lesser toe bony surgery be safely undertaken in an outpatient (non-laminar flow) setting?
   a. Not at all 0
   b. Yes, all 0
   c. Yes, soft tissue only 7
   d. Yes, bony but no metalwork 10
   e. Yes, including metalwork and implants 0
   f. Abstain 1

Session 3: Metatarsals

Chaired by Roland Walker

3.1. Metatarsal Stress Fractures in Athletes *Adrian Kendal*

- Metatarsal stress fractures are a common overuse injury in sport and account for approximately 20% of all stress fractures. The second and third metatarsals are most commonly affected. The 5th metatarsal is less commonly affected however carries with it a higher risk of healing issues and non-union.
- Relative Energy Deficiency in Sport (RED-S) is an increasingly prevalent phenomenon associated with athletic stress fractures, characterised by inadequate energy or resources available to meet physical demands. It is considered to be an evolution of the female athletic triad of amenorrhea, low bone density and low energy availability(1).
- RED-S is thought to comprise multiple mechanisms including suppressed bone formation, increased bone resorption, reduced sex hormone production and impaired recovery from repetitive loading. The consequences of this are reduced bone density, delayed fracture healing, increased stress fracture recurrence rates and an overall higher risk of multiple stress fractures.
- Current guidance supports the routine screening of RED-S in athletes presenting with stress fractures. At risk groups include long distance or endurance runners, triathletes, dancers, lightweight rowers and athletes with recent weight loss.

How should metatarsal stress fracture be worked up in athletes?

- Consideration should be given to nutritional, endocrine, biomechanical and training factors that can influence fracture risk. A focused nutritional history should include asking about restrictive eating, recent weight loss and dietary exclusions including vegan diets. Skipped meals and fear of weight gain could also be red flags.
- Changes in training schedule both in terms of frequency and intensity are relevant. Poor recovery can be a sign of energy deficiency and so questions relating to general fatigue, poor sleep and frequent illnesses should be asked. A history of previous stress fractures is clearly important as well as family history.
- Female athletes may manifest RED-S as amenorrhoea and therefore a detailed menstruation history should be taken including age at menarche, cycle regularity and presence of regular periods. Male athletes may present with reduced libido, a reduction in morning erections and low mood.
- Specific questionnaires have been developed to quantify energy deficiency in women and men including the LEAF-Q (Low energy availability in females questionnaire) and LEAM-Q tools. The female LEAF-Q has been validated and has good specificity for RED-S (approximately 90%)(2). Limitations of the LEAF/M questionnaires include failure to identify early or sub-clinical RED-S and a focus on the consequence of RED-S rather than diagnosing the condition before problems arise. Furthermore, LEAF-Q was validated in female endurance runners only and the generalisability of the tool remains uncertain.
- Examination should include a BMI calculation and an assessment of weight loss. BMI of twenty or below may point to low energy availability. In more severe cases patients may present with one or more stress fractures. Tendoachilles tightness and underlying deformity (e.g. cavus foot) may predispose a patient to overload of one or more metatarsals.
- Blood tests should include bone profile, iron studies and sex hormones including FSH, LH and testosterone or oestrogen depending on sex. Minimum Vitamin D levels in athletes should be above 75nmol/litre.

Management of Metatarsal Stress Fractures

- The consideration of whether to operate should be based on the presence of an underlying deformity that may be driving overload. For example a cavus foot will predispose a 5th metatarsal fracture.
- A systematic review by Goodloe et al. investigated surgical management of 5th metatarsals(3). They noted a pooled union rate of 96.7% with a mean time to union of 9.2 weeks. Return to play was 11.2 weeks on average with most returning to the same competitive level as before injury. Complications however were relatively common with an overall rate of 22.5% and refracture rate of 8.6%.
- Yates et al. performed a review of comparative literature with meta-analysis comparing operative vs non-operative management of 5th metatarsal base fractures(4). They presented a significantly lower non-union rate in the surgical group (2.6% vs 23.8%, $p < 0.001$). Time to union and return to sport were far superior in the surgical group (7.9 vs 15.6 weeks and 15.3 vs 30 weeks respectively). Operation rates beyond index treatment were also much higher in the non-operative group (31%) for those that went on to non-union versus the 8.5% re-operation rate in the surgical cohort for those patients requiring removal of metalwork.

- There is a paucity of evidence supporting non-operative management in this cohort. There is no strong evidence for cast immobilisation and patients should bear weight as tolerated whilst avoiding impact activities. Successful treatment and avoidance of refracture with or without surgery is highly dependent on addressing the initial risk factors for stress fracture.

Summary

Assessment of risk factors for RED-S is essential in the work-up of athletic patients presenting with metatarsal stress fractures and tools such as the LEAF-Q have a role. Examination is vital both in terms of assessing low BMI as an underlying cause as well as identifying underlying deformity that may pre-dispose excessive loading of a metatarsal. In athletic patients surgical fixation of 5th metatarsal stress fractures is supported by the literature.

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3.2. Non-union of base of 5th metatarsal fractures *Roland Walker*

- Base of 5th metatarsal fractures were first described by Robert Jones in 1902, an injury he sustained himself whilst dancing. Isolated 5th metatarsal fractures constitute 60% of all metatarsal fractures and of those 73% occur proximally.
- The Lawrence and Botte classification (1993) describes three fracture zones which each have different anatomical and biomechanical considerations(1).

Zone 1 injuries

- Zone 1 injuries are most proximal and represent avulsion type fractures of the tuberosity with soft tissue attachments from peroneus brevis dorsally and plantarly a slip of plantar fascia. They can be intra- or extra-articular.
- These injuries occur through foot and ankle inversion resulting in excessive pull from the soft tissue attachments. They are the most common 5th metatarsal base fracture accounting for 60-70% of cases. Minimally displaced fractures are considered stable and can be managed fully weight bearing in an aircast boot.

Zone 1 non-union, displacement and time to union

- Published non-union rates vary however most studies report a union rate of over 95% without the need for surgery. A retrospective cohort study by Pettersen et al. of 510 non-operatively managed zone 1 injuries demonstrated a mean time to fracture union of 7.5 weeks(2). There was a 2.7% non-union rate and weight bearing did not affect time to union nor union rate.
  A similar non-union rate of 3% was observed in an RCT by Nishikawa et al. assessing modes of non-operative management(3).
- A systematic review of zone 1 injuries by Rikken et al. reported a higher non-union rate of 9% in conservatively managed cases with a time to union of 8.5 weeks(4). The authors note that one of the included studies had a particularly high non-union rate and that is likely to have influenced the overall non-union rate. They reported a superior non-union rate of 4% in surgically managed cases with a mean time to union of 7.6 weeks. Displacement did not appear to significantly influence union rates in those managed non-operatively.
- Highly variable radiological parameters have been quoted as indications for surgical management including fracture displacement between 2mm and 20mm, more than 10 degrees of rotation of the proximal fragment and fracture involvement of more than one third of the 5th TMT joint. This guidance is not evidence based however.

- Evidence suggests that even in displaced fractures there is no clear benefit to acute surgical management(5). Lee at al. reported no difference in outcome between displaced or undisplaced zone 1 fractures regardless of whether they had surgery(6). There is no compelling reason to operate acutely on zone 1 fractures whether or not they are displaced.
- Surgery should be considered for the small proportion of patients that develop symptomatic non-union. Multiple surgical techniques have been described with no consensus on superiority. Small interfragmentary screws, hook plates or tension band wire constructs are recommended but the use of single intramedullary screw for zone 1 fractures is not advisable. Excision of bone fragments with reattachment of soft tissues using suture anchors has been described for avulsed fragments that are particularly small.

Zone 2

- Zone 2 is the true 'Jones' fracture resulting from inversion coupled with forced foot adduction. It occurs at the level of the facet between the 4th and 5th metatarsal base which is stabilised by the relatively strong intermetatarsal ligaments. This region is within a vascular watershed with anterograde blood supply from the metaphyseal arteries and retrograde blood supply from nutrient endosteal blood vessels and is implicated in non-union.
- Non-union rates in Zone 2 fractures have been quoted in many review articles at around 20%(5,7,8). Rikken et al. reported non-union in 18.3% of patients who were managed non-operatively versus 3.5% in those that had been treated with surgery(4). Trauma registry data from Pettersen et al. reported a 3.2% rate of non-union or conversion to surgery(2).
- Established literature has previously recommended non-weight bearing for patients with a zone 2 fracture however more recent evidence suggests that weight bearing is not a risk factor for developing non-union(2, 9). Overall evidence is limited and there are currently no randomised controlled trials evaluating weight-bearing status in zone 2 fractures.
- Look et al. reported outcomes of 47 patients treated with zone 2 fractures treated with a walking boot and found a relatively low radiological union rate of 66%(9). Despite this only 3 of the 17 non-union patients went on to have surgery. Asymptomatic fibrous non-union is a plausible explanation and therefore holistic evaluation of a patient beyond radiological assessment is warranted to avoid unnecessary surgery.

- Acute surgical management has been demonstrated to improve union rates and return to sport(RTS)(10). Mologne et al. conducted an RCT evaluating operative versus non-operative management in athletes and found that mean RTS was 8 weeks versus 15 weeks in those receiving surgery. Both non-union and re-fracture rates were lower in the surgical group. Acute surgical fixation should be offered to athletes and workers for whom early return to function is particularly important.
- Surgical technique primarily consists of intramedullary screw fixation with a minimum diameter of 4.5mm. If using partially threaded screws the threads should pass the fracture site to achieve compression however screw length should not exceed 68% of the metatarsal length to reduce the risk of fracture. The use of bone graft and PRP has been described in the literature however is probably unnecessary in acute fractures. The use of cancellous bone graft, for example from the calcaneus, is recommended in the management of non-union.
- Complications of surgery include damage to the sural nerve, non-union (0-5%), hardware breakage (up to 10% in athletes), hardware prominence with need for removal and chronic pain despite radiological union.

Zone 3

- Zone 3 injuries are more distal occurring at the metaphyseal-diaphyseal junction with soft tissue attachment from the peroneus tertius with relatively little ligamentous support. There is a paucity of evidence to support management decisions. Most of these injuries are stress fractures. Indications for surgery and technique are the same as Zone 2 injuries and an intramedullary screw could be used to facilitate earlier return to function. Cavus foot is a relative indication for surgical fixation and consideration should be given to definitive deformity correction.

Summary

- Base of 5th metatarsal fractures are common and the majority can be managed without surgery. Zone 2 injuries have a higher non-union rate but non-operative management is a viable treatment option in most cases. Surgery is recommended for patients requiring early functional union, including athletes, and for cases of non-union.

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3.3. Brachymetatarsia

Hisham Shalaby

Definition

- Brachymetatarsia is a congenital or developmental disorder characterised by a reduction in length of one or more metatarsals. It is defined by a shortening of at least 5mm that alters the normal metatarsal parabola(1). Shortening occurs at the metatarsal however the proximal phalanx can also contribute.

Epidemiology and Incidence

- It is extremely rare with a clinical incidence of 0.02-0.05%(2). It predominantly affects women more than men with a variable ratio of 14-25:1. Cases are often bilateral with a range of 47-75% and the 4th metatarsal is most commonly affected(3,4,5).

Aetiology and Associations

- It is thought to be the result of premature closure of the metaphyseal physis and can be congenital or acquired(6). There are many acquired causes including trauma, tumours and infection. It is associated with conditions including Trisomy 21, osteodystrophy, sickle cell and Turner's syndrome.

Presentation

- Patients commonly present with aesthetic concerns regarding a shortened and elevated toe(7,8). It can be associated with transfer metatarsalgia with telltale callosities and the affected metatarsophalangeal joint can sublux. Footwear difficulties are common and rubbing of the dorsum of the affected toe can be painful(8). Approximately 30% of cases will have an associated hallux valgus deformity. This can cause particularly bad transfer metatarsalgia due to offloading of the first ray in combination with the shortened lesser ray(10).

Investigations and Classification

- Investigations predominantly consist of standing radiographs to classify, confirm the degree of shortening and plan surgery. There is a role for cross sectional imaging in acquired cases.

- Lamm and Lamm developed a classification system based on which metatarsal is affected (number) and whether the metatarsal is short, deformed or tight (subluxed)(11). This guides surgical treatment in terms of lengthening, deformity correction and soft tissue releases.

Management

- Non-operative treatment is tailored to address the associated symptoms of shortening. Shoe wear modifications can be effective in cases of dorsal rubbing. A metatarsal dome orthotic and calf stretching can be effective in reducing pain associated with transfer metatarsalgia and forefoot overload.
- Options for surgical management consist of either lengthening at the affected ray or shortening of the neighbouring long metatarsal. Acute lengthening is recommended in deficits of up to 15mm however acute lengthening beyond this can cause undue stretch of nerves and blood vessels. Acute lengthening has a lower overall complication profile than the gradual technique. Bone graft options include calcaneus, iliac crest and fibula. Fixation options include k-wires and locking plates with interposition bone graft(12).
- For length deficits beyond 15mm gradual lengthening using an external fixator is recommended using the principle of distraction osteogenesis however this has been associated with a higher rate of complications(1). There is a latency period of 7 days before starting the lengthening process and the rate of lengthening is limited to 0.5mm per day. As such the duration of treatment is much longer and complications have been reported in up to 50% of cases including pin site infection and need for revision surgery.
- Shortening of neighbouring metatarsals can be useful in the management of transfer metatarsalgia but can also be used in combination with a lengthening procedure and also provides an option for autologous structural bone graft(13).

Conclusions

- Brachymetatarsia is very rare and surgical correction is technically challenging and associated with a significant complication rate, particularly for gradual lengthening.
- The principal complaint for most patients is usually aesthetic and functional consequences of the condition can be managed well with non-operative measures such as accommodative footwear.
- Choice of surgical technique will depend on the degree of shortening and patient expectations. There is no substantial evidence to support one surgical treatment over the other.
- Research questions remain regarding the type of osteotomy to use in acute lengthening, superiority of fixation techniques and optimal age to undergo surgery.

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3.4. Compartment syndrome of the foot

Claire Topliss

- Compartment syndrome occurs when pressure in an osseofacial compartment exceeds perfusion pressure. This can lead to irreversible nerve and muscle damage. Compartment syndrome of the foot is uncommon and occurs in approximately 2% of isolated foot trauma. It accounts for <5% of lower limb compartment syndrome cases.
- The diagnosis should be suspected in patients presenting with severe and progressive foot pain following trauma. Clinical examination is central to diagnosis.
- It is most commonly associated with a combination of significant crush and forefoot injury. It is estimated to occur in approximately 10% of calcaneal fractures however decompression is rarely performed (<1% of cases). The established standard of treatment is emergent fasciotomy although this remains controversial.
- A 2023 review of American College of Surgeons Trauma Quality Program's data analysed 70,525 foot fractures(1). Fasciotomies had been performed in 0.7% of cases. Open fractures, crush injuries and multiple fractures were the strongest predictors of developing compartment syndrome requiring fasciotomy. Male sex and presence of dislocation were also associated risk factors, increasing the likelihood by 64% and 48% respectively. Compartment syndrome was seen more commonly in level 3 trauma centres.

Pathophysiology

- Following trauma to a closed compartment haemorrhage and oedema cause increased interstitial fluid pressure. This leads to decreased capillary perfusion pressure and decreased tissue perfusion. Resultant tissue ischaemia causes capillary vasodilation and increased permeability leading to further oedema. Left unchecked this cycle can lead to muscle necrosis and nerve injury within the compartment. Muscle is most sensitive with irreversible ischaemia after 4-6 hours. Nerves are more resilient with reversible neurapraxia seen up to 1-4 hours and irreversible axonotmesis at 8 hours. A pressure of 30mmHg is the critical threshold for compartment syndrome however this is proportional to blood pressure.

Causes

- The most common cause of foot compartment syndrome is trauma, particularly crush injuries in combination with forefoot fractures. Other intrinsic causes include swelling following ischaemia and bleeding within the compartments. Extrinsic causes include tight bandaging, casts or splints and thermal injuries.

Compartment Anatomy

- Papers have described between 3 and 10 compartments of the foot. The most widely accepted model describes 9 compartments with 3 longitudinal (medial, lateral and superficial) and 6 confined to either forefoot or hindfoot including 4 interossei, an adduction and a calcaneal compartment(2). The calcaneal communicates directly with the deep posterior compartment of the leg via the flexor retinaculum.

Presentation

- Pain is the cardinal sign of compartment syndrome. Severe, unrelenting and progressive pain should raise suspicion. Examination can be challenging as many of the signs of compartment syndrome, including pain on passive stretch of the toe and firmness or decreased compressibility of the compartments, can be confounded by the underlying foot injury. Loss of 2 point discrimination is a relatively early sign with progression to paraesthesia and numbness in later stages. Late signs include pallor, a lack of pulses and paralysis. Serial examination is essential as signs and symptoms evolve over time.

Investigation

- Standard plain film radiographs are required to identify underlying fractures and dislocations. Compartment pressure monitoring has a role in supporting the diagnosis where examination findings are inconclusive or the patient has altered consciousness. A compartment pressure of >30mmHg or within 30mmHg of diastolic blood pressure (delta p) are consistent with compartment syndrome. Notably diastolic blood pressure can drop as a result of general anaesthetic therefore when calculating a delta p the conscious diastolic blood pressure should be referenced.
- Compartment pressure readings are not required to justify surgical decompression and in most cases the diagnosis can be made clinically.

Complications of Untreated Compartment Syndrome in the Foot

- Compartment syndrome of the foot can result in claw toe deformities secondary to a mismatch in power between the intrinsic and extrinsic muscles. In addition fibrosis and contracture of the plantar structures can lead to cavus deformity. In cases where ischaemia persists beyond 6 hours neuropathy can occur resulting in neuropathic pain or an insensate foot. Acute complications include intractable pain as well as rhabdomyolysis with associated kidney injury.

Non-Operative Treatment

- Timely reduction of dislocated joints or displaced fractures can relieve the intrinsic causes of compartment syndrome and prevent ischaemic progression. Removing extrinsic compression such as bandages and splints is also advisable as well as elevation of the affected limb. Analgesia has an important role both for pain management but also as a diagnostic tool. Fluid resuscitation with correction of hypotension is important for improving perfusion of the foot and reducing delta p.

Decompression

- BOAST guidelines advise ‘immediate surgical decompression’ following diagnosis of compartment syndrome. However, these guidelines are not specific to the foot. Current controversies relate to the number of compartments in the foot, whether or not we should decompress and how best to do so and consequences of decompression and functional outcomes following surgery.

Surgical Technique

- There are two principal approaches for fasciotomy of the foot. The dorsal approach consists of two incisions medial and lateral to the 2nd and 4th metatarsals respectively which allows access to the interossei as well as the deeper central compartment. This is particularly useful in forefoot crush injuries. The medial approach allows for decompression of all 9 compartments however can be technically challenging. A combination of the two can be used for severe crush injuries involving all compartments however skin bridge necrosis is a potential pitfall.

Timing and Problems with Fasciotomy

- Early surgery within 6 hours of onset can prevent irreversible ischaemic changes. Late fasciotomy is not likely to convey much benefit as irreversible tissue ischaemia has already occurred by this stage. However acute fasciotomy raises substantial wound management challenges.
- In one small case series of 14 patients undergoing fasciotomy, 11 required split thickness skin grafting and one underwent free tissue transfer for wound management(3). Skin grafted wounds are less durable in the long term and can cause tethering of the underlying tendons. Infection is a concern with delayed wound closure, particularly in the context of fractures with the potential to develop fracture associated infection.
- Fasciotomy wounds can be associated with nerve injury and may not allow access for fracture fixation. Other issues include chronic pain and stiffness as well as claw toe deformity despite decompression(4,5).

Managing Complications of Non-Operative Treatment

- Given the relatively poor outcomes reported following decompression it is worth considering how the complications associated with non-operative management might be mitigated. For mild deformity passive stretching, shoe wear modifications and orthoses may suffice. More severe deformity may warrant complex reconstruction including soft tissue releases, tendon transfers, osteotomy or fusion. Chronic nerve pain may be managed with neurolysis or nerve decompression. Amputation remains a salvage option for severe cases refractory to treatment.

Pie-crusting (Dermal Fenestration)

- A surgical alternative to fasciotomy is the pie crust technique which was described by Dunbar et al. in 2007(6). A 15 blade is used to make multiple 3-5mm dorsal incisions and a haemostat is opened within each wound to stretch the deep fascia and evacuate haematoma. This technique has been augmented more recently with the use of a negative pressure wound therapy(7).

Synthesis

- The long term outcomes of foot compartment syndrome appear to be similar with or without management with fasciotomy. There is no level 1 evidence that fasciotomy prevents sequelae. Many of the complications of non-operative management, particularly deformity, can be managed effectively with surgery. Neuropathic pain remains a concern however it is not clear that fasciotomy makes a significant difference. Pie crusting can reduce swelling without the elevated risks of fasciotomy.
- There is a paucity of robust evidence on optimal management in foot compartment syndrome. A 2025 systematic review reported most of the evidence consisted of case reports and small cohort studies, most of which were managed with fasciotomy(8). They were unable to provide a consensus on the number or anatomical locations of fasciotomy wounds and no metaanalysis was possible.

Conclusion

- Fasciotomy remains the widely accepted standard of treatment for compartment syndrome of the foot however this is contentious and not supported by robust evidence. Management of this rare condition is controversial and future research and debate should centre around acute decompression versus late reconstruction.

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Consensus Questions

1. Should metatarsal stress fractures be treated empirically with vitamin D supplementation?
   a. Yes 18 (90%)
   b. No 2 (10%)
2. What dose vit D would you prescribe for empirical treatment of metatarsal stress fractures?
   a. 1000 units/day 2 (10%)
   b. 2000 units/day 13 (65%)
   c. 4000 units/day 3 (15%)
   d. No preference 2 (10%)
3. Should patients with RED-S and MT stress fractures be referred to a physician for routine work-up?
   a. Yes 18 (90%)
   b. No 1 (5%)
   c. Abstain 1 (5%)
4. Does MRI have a routine role in assessing union or return to play in MT stress fractures?
   a. Yes 0
   b. No 20 (100%)
5. At what time point following index injury is non-union of a base of 5th metatarsal fracture defined?
   a. >6 months 2 (10%)
   b. 6 months 12 (60%)
   c. 4 months 4 (20%)
   d. Abstain 2 (10%)
6. Non-operative management in a CAM style walker boot for 6 weeks is a reasonable initial treatment for the majority of base of 5th MTs regardless of type.
   a. Yes 20 (100%)
   b. No 0
7. There should be a route of access to fracture clinics for high demand individuals (e.g athletes and manual workers) who wish to consider acute fixation of base of 5th MT fractures in Zones 2 and 3.
   a. Yes 19 (95%)
   b. No 1 (5%)

8. Lengthening surgery for brachymetatarsia is a rare, specialised operation and should be referred to individuals who manage this in high volumes.
   a. Yes 19 (90%)
   b. No 1 (5%)

9. It is reasonable to offer lengthening surgery for brachymetatarsia purely for the psychosocial element of the condition.
   a. Yes 8 (40%)
   b. No 11 (55%)
   c. Abstain 1 (5%)

10. Emergency fasciotomy should be the recommended standard of care for the management of foot compartment syndrome.
   a. Yes 0 (90%)
   b. No 17 (85%)
   c. Abstain 3 (15%)

11. There may be a role for pie crusting as an alternative to fasciotomy in compartment syndrome of the foot.
   a. Yes 14 (70%)
   b. No 0
   c. Abstain 6 (30%)

12. I have clinical experience of pie crusting of the foot in the context of trauma.
   a. Yes 4 (20%)
   b. No 16 (80%)

Session 4: Tarsometatarsal Joints

Chaired by Carolyn Chadwick

4.1 and 4.2. Management of Lisfranc Injuries

Carolyn Chadwick and Lyndon Mason

Introduction

The Lisfranc injury spans a rich spectrum, from a mild midfoot sprain through to a frank fracture-dislocation that may extend into the hindfoot. It is uncommon - quoted at approximately 0.2% of all orthopaedic injuries - yet its importance is out of proportion to its incidence, because the anatomy is complex, difficult to visualise on plain films, and quoted in the literature to have between 20% and 40% of injuries missed at first presentation. Missed instability results in chronic midfoot pain, degenerative change, progressive arch collapse, forefoot abduction, altered gait and instability on push-off. Ultimately, the outcome is determined less by the choice of surgery or implant used than by the accuracy of reduction and the vigilance of diagnosis.

Mechanism of Injury

Approximately 70% of Lisfranc injuries are high-energy, e.g. road-traffic collisions, falls from height and crush injuries.

The typical mechanism is an axial load combined with a rotational force applied through a plantar-flexed foot: a hyperflexion, compression and abduction moment is exerted on the forefoot and transmitted to the tarsometatarsal articulation, displacing the metatarsals dorsally and laterally.

These injuries tend to produce more severe fracture-dislocations, often with lateral-column involvement.

The remaining injuries are **low-energy** - sporting and twisting mechanisms - which produce more subtle, predominantly ligamentous disruptions.
It is this second group that has driven the modern emphasis on weight-bearing assessment, because the instability may be invisible on a static, non-weight-bearing film.

Clinical Presentation

The history of an appropriate mechanism should raise suspicion.
Presenting features include severe midfoot pain, marked swelling, plantar ecchymosis and an inability to bear weight; deformity is present only in more significant injuries. Plantar bruising in particular is a classic sign.
Because the physical signs of a subtle injury can be unremarkable, **a high index of suspicion remains the single most important safeguard against a missed diagnosis,** especially in the polytrauma patient in whom distracting injuries divert attention from the foot.

Diagnostic Imaging

Assessment begins with non-weight-bearing radiographs - standard anteroposterior, lateral and oblique views. Where an obvious fracture-dislocation is present, the diagnosis is made and attention turns to surgical planning.

The pitfall is the painful midfoot with a normal non-weight-bearing film: such an image does not exclude injury. In this situation, weight-bearing radiographs, computed tomography (CT), or both, are required.

Weight-bearing imaging is the key investigation and can be deferred until the patient can tolerate it, typically 10-14 days after injury.
Bilateral weight-bearing films allow comparison with the uninjured side, since a small degree of physiological widening may be normal for a given patient.

A recurring quotation from the literature is that Lisfranc fracture-dislocation is misdiagnosed in approximately 20% of emergency-department presentations (Lau et al., 2017)[1]. Which emphasises the importance of a defined referral pathway for suspicious cases, ie every patient with midfoot pain after trauma, to be directed to weight-bearing views to detect subtle instability.

Computed Tomography and Weight-Bearing CT

CT, and preferably weight-bearing CT (WBCT) if available, detects occult fractures and comminution, defines the extent of injury and aids surgical planning.

A 2026 systematic review reported that WBCT offers superior sensitivity, specificity and diagnostic accuracy for these injuries, particularly the subtle patterns, although access to weight-bearing scanners remains limited in most units[2].

The value of cross-sectional imaging is quantified by the observation that CT reveals around 60% more metatarsal fractures and roughly twice as many tarsal fractures as plain radiography as coined by Preidler et al[3].

Data from a retrospective review of preoperative xrays and CT scans of 175 patients who underwent surgery for Lisfranc injuries illustrated how much injury is invisible on radiographs when CT is taken as the reference standard (Under submission, full article not published yet)[4]. The largest discrepancies between radiographs and CT were for fractures of the lateral cuneiform (87% missed on radiographs), cuboid (80% missed), navicular (63% missed), medial cuneiform (61% missed) and first metatarsal (52% missed).

The corresponding diagnostic performance is shown in Figure 1: plain-film sensitivity for the lateral cuneiform was as low as 7.9% and for the cuboid 18.4%. **The practical message is that much of what is labelled a "purely ligamentous" injury may in fact harbour lateral-column fractures that are simply not seen without CT scans.**

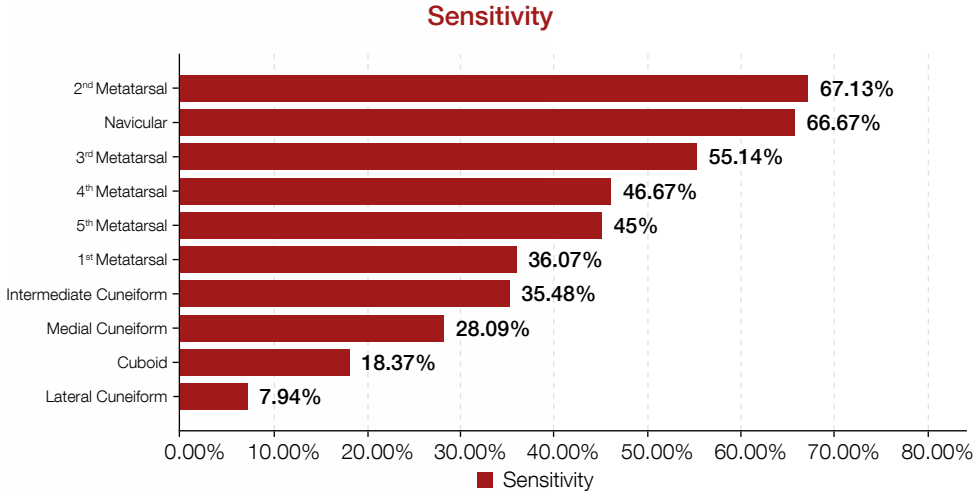


Figure 1 - Sensitivity of plain radiographs for midfoot fractures, referenced against CT in a 175-patient institutional series. Sensitivity is low for the lateral column (lateral cuneiform, cuboid) despite preserved specificity.

Zhang et al attempted to classify Lisfranc injuries using three-dimensional fracture lines and a heat map by retrospectively analysing CT scans from 157 patients and projecting their fracture lines onto a standardized 3D foot model, the researchers identified specific high-density fracture zones.
The fracture lines not involving the TMT joint are mainly located in the medial aspect of the first metatarsal trunk and the fifth metatarsal trunk[5].

Magnetic Resonance Imaging

MRI is reserved for the query purely ligamentous injury - the patient with persistent symptoms and normal radiographs and CT - and is adjunctive rather than definitive[6].

Rupture or grade-2 sprain of the plantar ligament running from the medial cuneiform to the bases of the second and third metatarsals is highly suggestive of an unstable midfoot, whereas a normal-appearing ligament suggests stability[7].

Stress Views

Stress views described in the literature include:

The abduction stress AP view (Foot & Ankle International, 1998)[8], in which a line tangential to the medial navicular and medial cuneiform normally intersects the base of the first metatarsal - the line intersected the first metatarsal base in 39 of 40 uninjured volunteer feet and in all nine cadaveric feet before sectioning, and was disrupted in every cadaveric foot once the Lisfranc and dorsal tarsometatarsal ligaments were divided[8].

The push-up test (Smith, BJJ, 2015)[9], in which a force applied under the second metatarsal attempts to elevate its base away from the middle cuneiform on the lateral radiograph; all 12 cadavers in that study displaced by more than 2mm[9].

Functional Anatomy

Understanding the anatomy is the key to both diagnosis and treatment. Sarrafian's classic description (Anatomy of the Foot and Ankle, 1993)[10] recognised a medial column formed by the talonavicular, naviculocuneiform and first-to-third tarsometatarsal joints, and a lateral column formed by the calcaneocuboid and fourth-to-fifth tarsometatarsal joints.

Functionally, the foot behaves as two units: a stiff medial (and central) column comprising the three medial rays, and a more mobile lateral column. Restoring the correct relative lengths of these longitudinal columns is central to recovering function after injury.

Stability of the complex is provided by a combination of bony and soft-tissue constructs (Figure 2). The Lisfranc joint complex consists of the articulations between the five metatarsal bases, three cuneiforms and cuboid.
The recessed base of the second metatarsal sits in a mortise and acts as the keystone of the transverse (“Roman”) arch; disruption here causes loss of midfoot stability and abnormal load transfer.

Stability is largely provided by the Lisfranc ligament complex - the dorsal, interosseous and plantar bands connecting the medial cuneiform to the second metatarsal base - of which the interosseous band is the strongest, roughly 1cm wide, and the last to fail on cadaveric testing[11,12].

The Transverse ("Roman") Arch of the Midfoot

Coronal section through the tarsometatarsal (Lisfranc) joints

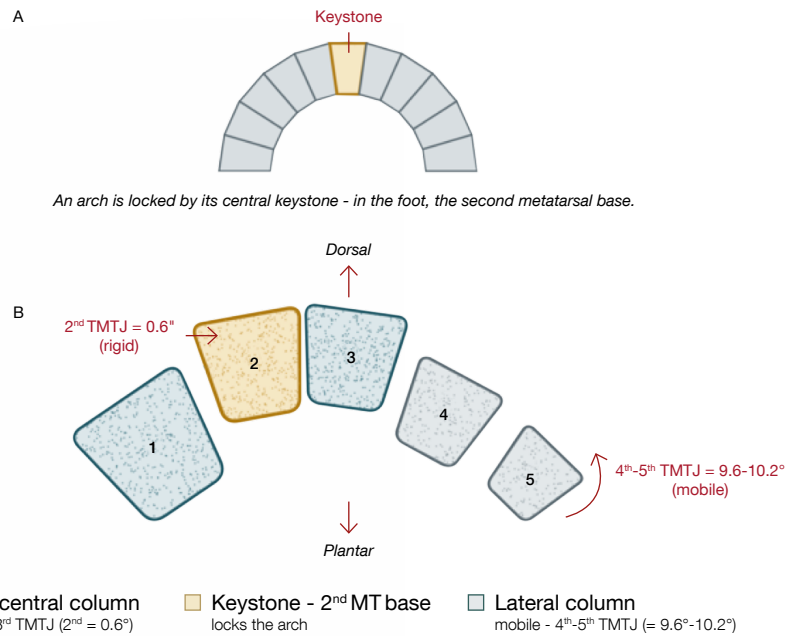


Figure 2 - Functional columns of the midfoot and the Lisfranc ligament complex. The recessed second metatarsal is the keystone of the transverse arch; the medial and central columns are relatively rigid while the lateral column is mobile.[13]

A related structure was the Lateral Lisfranc Ligament running from the base of the second to the fifth metatarsal base. It binds the second-to-fifth metatarsals, contributes to a suspensory mechanism of the foot, and attaches to the short plantar ligament so that, on rising to tip-toe, it provides elastic re-formation of the transverse metatarsal arch.

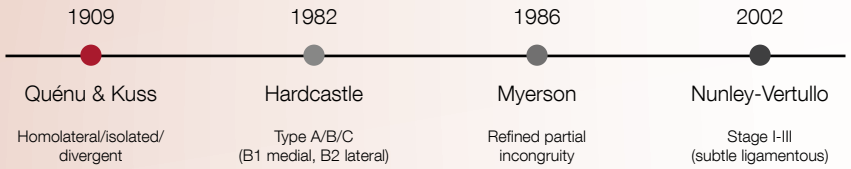
This explains why static weight-bearing imaging - taken with a flat foot - may under-represent instability that would be provoked in a tip-toe stance.

Classification - Does It Still Matter?

Lisfranc injuries have been classified repeatedly since the early twentieth century (Figure 3). Quénu and Kuss (1909)[14] described homolateral, isolated and divergent patterns; Hardcastle (1982)[15] defined types A, B (B1 medial, B2 lateral) and C; Myerson (1986)[16] refined the description of partial incongruity; and Nunley and Vertullo (2002)[17] staged the subtle, predominantly ligamentous injury I-III.

These systems are descriptive and convey injury severity, but they largely address the transverse injury pattern rather than the longitudinal instability that matters most for restoring column length, and they carry limited prognostic value, particularly for subtle injuries. Contemporary practice therefore favours a simpler, more reproducible framework: stable versus unstable, displaced versus non-displaced, and purely ligamentous versus fracture associated.

Evolution of Lisfranc Injury Classification Systems



Descriptive systems capture transverse injury severity but have limited prognostic value, especially for subtle injuries. Contemporary practice favours: stable vs unstable · displaced vs non-displaced · purely ligamentous vs fracture-associated.

Figure 3 - Timeline of the principal Lisfranc classification systems. Descriptive systems grade transverse severity but have limited prognostic value; contemporary practice favours a stability-based framework.

Non-Operative Treatment

Non-operative management is appropriate for stable injuries with minimal displacement - conventionally less than 2mm on a weight-bearing radiograph. Outcomes are good only if stability is maintained, so close follow-up with serial radiographs is essential, because any missed instability leads to poor results. Non-operative treatment may also be chosen for non-ambulatory patients or those with severe comorbidities such as peripheral neuropathy or peripheral vascular disease, accepting that some loss of foot shape and function may follow and can be addressed later if necessary.

In a 2015 series of 36 patients: all began with non-operative management, but 20 failed on subsequent radiographs and were converted to screw(9) or suture button(11) fixation. The mean AOFAS score was higher in the operatively treated group (92.8 ± 8.4) than in those managed non-operatively (75.3 ± 15.8) $p < 0.0001$[18].

Stødle et al. (2022) followed 26 patients presenting within four weeks of injury with less than 2mm displacement on weight-bearing and comparative views, treated in a non-weight-bearing cast for six weeks (with a further four weeks in a boot if still painful) and monitored with serial radiographs. At one year the median AOFAS midfoot score was 89 with a VAS of 0 and only one patient developing osteoarthritis; scores continued to improve, reaching 100 at final follow-up (median 55 months)[19].

Marsland et al. (2022) systematically reviewed conservative management (eight papers, seven retrospective) and found widely varying outcomes, high rates of conversion to surgery, no agreed definition of stability and no agreed treatment protocol, while underlining the importance of modern imaging[20].

A multicentre randomised controlled trial by Ponkilainen et al, of 27 patients found no difference in VAS-FA at two years between operatively and non-operatively treated nondisplaced Lisfranc injuries, but the study was underpowered[21].

Operative Treatment

Where surgery is indicated, anatomical reduction and stable fixation are the key predictors of outcome, together with restoration of column length. The available strategies are percutaneous fixation, open reduction and internal fixation (ORIF) and primary arthrodesis (PA).

The classic evidence base is Myerson's 1986 series of 55 injuries reviewed at a mean of 50 months, in which good or excellent results rose steeply with the adequacy of treatment: 0% after plaster alone, 20% after closed reduction, 53% after closed reduction with fixation and 77% after ORIF (Figure 4)[16].

Overall, an acceptable reduction yielded 85% good or excellent results against 17% for an unacceptable reduction. Prognosis was poor with non-anatomical reduction or unreconstructable comminuted, crush injuries and purely ligamentous patterns, and correlated positively with accuracy of reduction and maintenance of the longitudinal arch.

The enduring conclusion - that prognosis depends on the accuracy and stability of reduction - has been repeated by every subsequent study.

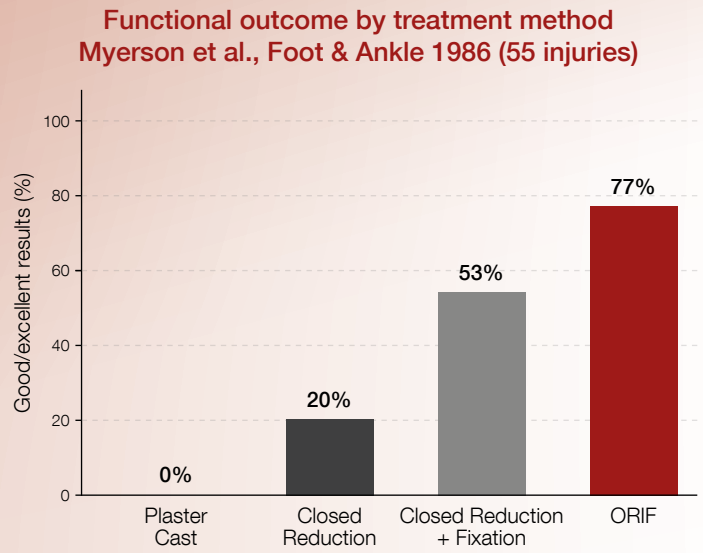


Figure 4 - Good/excellent outcomes by treatment method in Myerson et al. (1986); results improved with the adequacy of reduction and fixation, from plaster alone to ORIF.

Percutaneous Fixation

Percutaneous fixation is reserved mainly for subtle, low-energy injuries without lateral instability, and only when an anatomic (or near-anatomic) reduction can be achieved closed.

In a case matched comparison of percutaneous reduction and internal fixation (PRIF) of low energy Lisfranc injuries with a matched, control group of patients treated with ORIF, 16 patients each, the percutaneous group had significantly better AOFAS and MOXFQ scores than ORIF at 43 months (Chen et al., 2021)[22]. A retrospective review of 22 patients with low energy Lisfranc injuries treated with percutaneous reduction and screw fixation reported anatomic or near-anatomic reduction in all, with excellent rates of return to work, function and sport (Wagner et al., 2013)[23]. A systematic review of four studies concluded that percutaneous fixation is simple, safe and associated with low morbidity (Stavrakakis et al., 2019)[24].

Comparative series of percutaneous versus open reduction have, however, cautioned that reduction quality can suffer: in one study only 2 of 6 (33%) closed reductions were acceptable versus 19 of 22 (86%) open (Schepers, 2013),[25] and a further series reported four malreductions among 19 percutaneous cases versus none among 13 open (Walter, 2015)[26].

The consensus of the evidence was that anatomic reduction is paramount: the open approach is preferred for displaced injuries, with percutaneous fixation acceptable for low-energy, minimally displaced patterns.

ORIF Versus Primary Arthrodesis

ORIF was traditionally preferred to preserve joint motion, but high rates of hardware failure, post-traumatic osteoarthritis and secondary arthrodesis have challenged that position. The early comparative literature pointed in both directions: Ly and Coetzee studied 41 patients with primarily ligamentous injury; a primary stable arthrodesis of the medial two or three rays appears to have a better short and medium-term outcome than open reduction and internal fixation of ligamentous Lisfranc joint injuries;[27] Rammelt found that primary ORIF of fracture-dislocations produced better function, earlier return to work and greater satisfaction than secondary (salvage) corrective arthrodesis;[28] Henning's prospective randomised trial found no meaningful difference between primary fusion and ORIF, the higher reoperation rate after ORIF being largely explained by routine metalwork removal;[29] and Sheibani-Rad and Coetzee's 2012 qualitative systematic review of six articles (193 patients) found a one-year mean AOFAS of 72.5 after ORIF and 88.0 after arthrodesis, concluding that both procedures gave satisfactory results[30].

Since 2020 three randomised controlled trials have compared the approaches. Ponkilainen et al. (2024, Finland; 43 patients, multicentre) found no difference in FA-VAS or AOFAS at 24 months, although fixation methods and implants were not standardised and the study underpowered[31]. In a randomized controlled trial by Stødle et al., 48 patients presenting with Lisfranc injuries were randomised into internal fixation (IF) or primary arthrodesis (PA) cohorts and tracked over a two-year period. Patients in the PA group underwent primary fusion of the three medial tarsometatarsal joints (TMTJs). The IF protocol utilized a temporary bridge plate across the first TMTJ, while the second and third TMTJs were fused. Subsequent evaluations revealed no significant differences between the groups with regard to SF-36 or VAS pain scores or AOFAS Score at 2 years[32].
Sun et al. (randomised 78 patients all with first-TMTJ fracture-dislocation into ORIF(40) or PA(38) found that primary arthrodesis of the first TMTJ outperformed ORIF on AOFAS midfoot, FAAM, SF-36 pain and VAS scores, preventing re-dislocation, pain and revision, and concluded that PA is indicated where the first TMTJ is dislocated[33].

Carter et al. (JBJS, 2023) provided a critical analysis review, noting that the meta-analyses to that date showed at most statistically - but not clinically - significant differences, and that the higher reoperation rate after ORIF is explained by routine hardware removal[34].

A 2024 systematic review and meta-analysis of the randomised trials (241 patients, 5 RCTs; Mactier et al.) found no significant difference in functional scores (AOFAS, SF-36) or in unplanned return to surgery between PA and ORIF. However, primary arthrodesis (PA) had lower two-year VAS pain (mean difference 0.89, P=0.01), higher satisfaction and lower overall return to surgery - the VAS pain difference of under one point might not reach the minimal clinically important difference, and heterogeneity was substantial[35].

A larger 2024 meta-analysis pooling 18 studies (5 RCTs and 13 comparative cohorts; O'Connor et al.) shifted the balance towards primary arthrodesis[36]. It reported better AOFAS and VAS scores, lower rates of post-traumatic arthritis (2.8% versus 17.3%), lower unplanned reoperation (approximately 14.2% versus 22.6%) and better return to pre-injury activity (79.2% versus 65.7%) after arthrodesis; complications not requiring revision were similar between groups. Post-operative patient-reported outcomes favoured PA in 44% of studies and ORIF in 25%, with similar results in 31% Figure (5); **when only RCTs were analysed, patient-reported outcomes did not differ.** The authors concluded, with moderate certainty, that PA improves AOFAS scores, reduces reoperation and improves return to activity in the short and medium term.

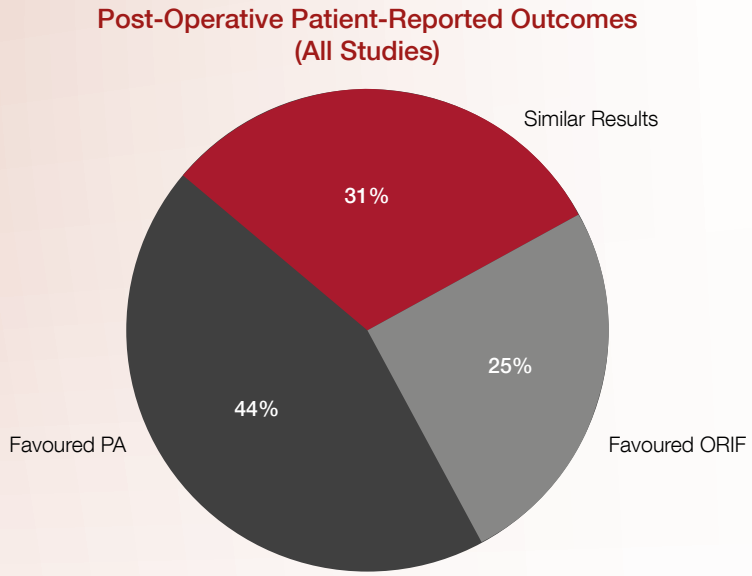


Figure 5 - Post-operative reported PROMs for PA vs ORIF

In parallel, the accumulated data show a marked rise in the rate of primary fusion - from around 8% to as much as 43% (Segal et al)[37] - as practice has evolved, particularly for purely ligamentous injuries, which heal more slowly than bony injuries (Mohamed et al)[38] and in which fusion reduces reoperation risk.

Fixation Type: Screws, Plates and Staples

For open fixation, transarticular screws are cheap, less bulky and require a smaller incision, but risk chondral damage, may break and can be troublesome to remove; dorsal bridge plates spare the articular surface but require a larger exposure and raise the question of later removal. A retrospective review of 108 patients (Kirzner et al., JBJS, 2018) reported mean AOFAS scores of 82 for dorsal bridge plating, 71 for transarticular screws and 63.3 for combination fixation, the poorer combination result might be reflecting its use in more severe injury patterns; patient satisfaction was similar across groups[39].
A systematic review of four observational studies (111 plating versus 87 screws; Engelmann et al., 2022) found better AOFAS after plating (MD 7.08, 95% CI 1.50-12.66, p = 0.01), although it is not known if this is over the minimal clinically important difference, no difference in infection, hardware removal or chronic pain, and a higher incidence of post-traumatic osteoarthritis with screws[40].
A systematic review and meta-analysis of 210 patients at a mean of 40.6 months (Boksh et al., 2020) again found better AOFAS with dorsal bridge plating but no difference in the Foot Function Index, osteoarthritis or metal failure, and cautioned that the literature is too scarce for robust conclusions[41].

Dombrowsky et al. studied nitinol staple fixation in comparison to plate and screws constructs in primary arthrodesis for acute Lisfranc fracture-dislocation,[42]

The primary measure was the successful arthrodesis of each treated joint. Radiographic outcomes were evaluated per individual joint, with the fixation methods categorized as follows:

- Staples exclusively: 45 patients (154 joints)
- Hybrid construct (staples, plates, and screws): 45 patients (40 joints)
- Plates and screws exclusively: 31 patients (111 joints)

Analysis found non-union to be more likely with plate-and-screw constructs (9.0%, 10/111) than with hybrid (2.5%, 1/40) or staple-only (1.3%, 2/154) fixation.

Across all of these studies, however, the recurring conclusion is that anatomic reduction is more predictive of outcome than the choice of fixation.

Flexible (Suture-Button) Fixation

Flexible devices such as suture buttons have gained favour on the basis of biomechanical studies suggesting that they permit physiological micromotion while maintaining reduction; they are not suitable for first-TMTJ instability, and most clinical evidence is level III-IV. A retrospective case-control study of 32 screws versus 31 tightropes found no difference in functional outcome or stability at one year, the suture-button group performing better initially at 6 months, but no statistically significant difference after screw removal at 1 year or final follow up (Cho et al., 2021)[43]. A series of 84 patients using a suture button with a supplementary intercuneiform screw reported mean return to full weight-bearing in an orthotic at 11 days, no failures and a rise in AOFAS from 31 to 90 at three years.[44] A systematic review of 10 studies (186 patients, ages 13-72) reported 100% return to sport or activity at 10.8-25.9 weeks, AOFAS scores of 83.5-97, VAS of 0.6-2.5 and a 7.7% complication rate (two diastases, two paraesthesiae, one hardware irritation and one case of osteoarthritis), while noting that larger, randomised studies are needed for definitive conclusions[45].

More recent systematic-review data for ligamentous Lisfranc injuries (249 ligamentous injuries; Balboni and Webber et al., 2025-2026) suggested that suture-button fixation produces superior outcomes compared with rigid ORIF for unstable ligamentous injuries (Figure 6): higher AOFAS (95.5 versus 89.4), lower complications (10.9% versus 18.2%), lower failures 0% versus 4.9%, no secondary procedures versus 30.5%, and faster return to sport (4.2 versus 8.9 months).[46,47] These early findings must nonetheless be read with caution: the contributing series were small and patients were followed for comparatively short periods. Mean follow-up in the ORIF cohort was also more than double that of the suture-button cohort, so some of the difference in reported complication rates may reflect the longer period over which those patients were observed. On the evidence currently available, suture-button fixation is best regarded as a motion-preserving alternative that appears to reduce metalwork-related morbidity and the need for further surgery, though confirmation awaits longer-term data.

General indications are an unstable ligamentous injury requiring surgery, an athlete in a flexibility-dependent sport, a patient unable to undergo planned hardware removal, isolated Lisfranc ligament disruption with minimal bony involvement, and a confirmed stable anatomic reduction intraoperatively; cautions to be considered are bony or fracture-dislocation patterns, comminution or cartilage loss, multi-joint involvement and poor bone quality.

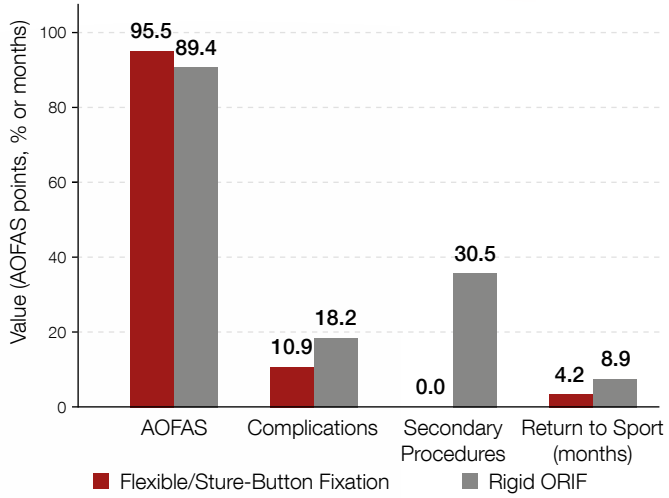


Figure 6 - Flexible (suture-button) fixation versus rigid ORIF for unstable ligamentous Lisfranc injuries from pooled systematic-review data: higher AOFAS, fewer complications and secondary procedures, and faster return to sport with flexible fixation

The Lateral Column

The lateral column deserves specific attention and is the subject of a cautionary analysis. Temporary Kirschner-wire stabilisation of the lateral column, often removed before the ligaments have healed, was questioned: in a three-centre cohort of 222 lateral column injuries, lateral-column injury virtually never occurred in isolation - it was associated with a central-column injury in 99.6% of cases and a medial-column injury in 70.6%. Most patients (63%) had no lateral-column fixation, yet only 2.84% lost alignment by six months, whereas Kirschner-wire fixation was associated with a higher rate of alignment loss (5.9%) and plates and screws with none[48]. On multivariate regression, purely ligamentous injury independently increased the risk of malalignment, while central-column bridge plating was protective - consistent with a lateral suspensory ligament that re-tensions the transverse arch once the central column is reduced. The wider point echoed throughout the presentation is not to forget the lateral column, but to reduce it by restoring the central column rather than by routine wiring.

Metalwork Removal

Whether to remove metalwork electively remains contested.
A national consensus survey of UK practice (Rhodes et al., The Foot, 2021) found that 38% of surgeons routinely remove metalwork, at a median of six months (interquartile range 4-10), despite the absence of solid evidence that removal optimises physiological function or reduces the risk of metal breakage[49].
Retention has been shown to be safe with comparable outcomes to routine removal (Onochie et al., 2023)[50] and no functional difference on the MOXFQ (Kamel et al., 2025, although only 18 patients were available at final telephone follow-up)[51].The implications of a policy of routine removal - for patient counselling, cost-effectiveness and healthcare utilisation - have themselves been examined (Saha et al., 2023)[52].

A Practical Pathway

The presenters converged on a pragmatic, individualised ("à la carte") pathway consistent with the algorithm of Carter et al. (JBJS, 2023)[34].

A suspected Lisfranc injury, identified from mechanism and clinical findings, proceeds to non-weight-bearing radiographs; an obvious fracture-dislocation moves directly to surgical planning, while a normal or equivocal film prompts weight-bearing radiographs with bilateral comparison or a CT scan depending on ability to bear weight and, where a purely ligamentous injury is suspected, MRI. Confirmed stability with less than 2mm displacement is managed non-operatively with vigilant follow-up and serial films; instability is treated operatively, choosing between percutaneous fixation, ORIF and primary arthrodesis according to the injury pattern. Across every branch of the pathway, anatomic reduction and restoration of column length are the dominant determinants of outcome, and the method used to achieve them is secondary.

Long-Term Outcomes

A comprehensive 2025 review (Mohamed et al.) reported post-traumatic osteoarthritis in 50-70% of patients at two years, chronic pain in 25-30%, and complex regional pain syndrome in 5-8%. Malunion or flatfoot in 15-20% where reduction was suboptimal[38].

A long-term series of 61 patients followed for a mean of 10.9 years (JBJS Am, 2016) found radiographic osteoarthritis in 72% and symptomatic osteoarthritis in 54.1%, with non-anatomic reduction as a major risk factor[53].

The persistent message is that anatomic reduction is the single most important determinant of long-term outcome, that radiological osteoarthritis correlates poorly with symptoms, and that functional outcome measures are the preferred endpoints.

Summary

- The injury is commonly **missed**; a high index of suspicion and a defined referral pathway for post-traumatic midfoot pain are the best safeguards.
- **Stable injuries** (<2mm displacement) do well non-operatively but require vigilant follow-up with serial films.
- **Anatomic reduction and restoration of column length** - not the choice of implant or fixation method - are the dominant determinants of outcome.
- **Primary arthrodesis** has an expanding role, particularly for purely ligamentous injuries and complete fracture-dislocations; flexible fixation shows promise in athletes with unstable ligamentous injuries.
- Treatment should be **individualised depending on injury pattern and number of rays involved.**
- There is no evidence to support **routine removal of metalwork.**

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4.3. Tarsometatarsal Joint Arthritis

Adam Lomax

Introduction

Arthritis of the tarsometatarsal joints is a demanding problem, the central challenge is to relieve pain without destabilising a finely balanced arch. The aim of treatment must respect the very different roles of the medial, central and lateral columns of the midfoot. The evidence base is comparatively thin and much of it is indirect - drawn from studies of Lapidus fusion, acute trauma or extended midfoot reconstruction rather than from isolated tarsometatarsal arthritis.

Anatomy and Biomechanics

The midfoot is arranged in three columns: a medial column (first TMTJ), a central column (second and third TMTJs) and a lateral column (fourth and fifth TMTJs), organised in the coronal plane as a Roman arch with the second metatarsal as its keystone. Stability is secured by the Lisfranc ligament, running from the medial cuneiform to the second metatarsal base, and by interosseous ligaments across the lesser metatarsal bases. The midfoot acts as a beam, translating the forward propulsion of the ankle and hindfoot to the forefoot between heel rise and toe-off, converting a flexible foot at heel strike into a rigid lever at toe-off. The medial joints are stiff while the lateral joints are mobile, allowing balance and accommodation to uneven ground.

These roles are quantified by two cadaveric studies. Ouzounian and Shereff (1989) measured motion in dorsiflexion and plantarflexion, finding the greatest movement at the fourth and fifth TMTJs (means of 9.6° and 10.2°) and the least at the second TMTJ (mean 0.6°), with a similar trend in pronation-supination[1]. Lakin et al. (JBJS Am, 2001), studying contact mechanics in six normal feet, found that the second and third TMTJs bore the majority of force in all foot positions compared with the first, fourth and fifth - which may explain why second- and third-TMTJ osteoarthritis is more common in the absence of trauma[2].

Aetiology

Tarsometatarsal arthritis may be degenerative, post-traumatic, inflammatory (including rheumatoid disease, gout and calcium pyrophosphate deposition), neuropathic, or secondary to hindfoot fusion or deformity. The degenerative and post-traumatic forms are the most frequently encountered.

Diagnosis

The history should note trauma and systemic disease (diabetes, rheumatoid arthritis, inflammatory arthropathy, gout, calcium pyrophosphate deposition). Examination frequently reveals dorsal osteophytes and midfoot pain, and the piano-key test (Keiserman et al., 2003) is used to identify subtle tarsometatarsal pathology;[3] deformity, collapse, a rocker-bottom contour and forefoot abduction may be present.

Weight-bearing radiographs are routine. MRI is used by some to define the degree and extent of arthritis and whether the rest of the midfoot is involved - a point of medicolegal relevance where limited fusion is planned - and SPECT-CT can be useful where available. Diagnostic and therapeutic injections may be performed under ultrasound, fluoroscopic or CT guidance; ultrasound improves accuracy over palpation alone at the first and second TMTJs (Khosla et al., 2009),[4] but injections can be inaccurate in localising pathology because local anaesthetic and steroid leak between the several communicating joints, so that one injection may fill more than one joint.

Non-Operative Management

Simple oral analgesia is used; topical analgesics have no demonstrated benefit in the foot and ankle. Orthoses aim to reduce hindfoot eversion and support the medial longitudinal arch. A randomised controlled trial of foot orthoses in midfoot osteoarthritis (Halstead et al., 2016), showed improved pain and function over a 12-week period compared with a sham insert;[5] full-length inserts reduced midfoot loading and gave better symptom control than three-quarter-length inserts (Rao et al., 2009)[6].

Corticosteroid Injections

Corticosteroid injections offer both diagnostic and therapeutic benefit and ideally should be image-guided, but there are no studies specific to the tarsometatarsal joints; the evidence comes from cohort studies spanning multiple joints and pathologies. Grice et al. (2017) reported 86% improvement with recurrence at a mode of three months;[7] Ward et al. (2008) found improvement in scores up to six months;[8] and Protheroe et al. (2018) found a significant difference in the response of midfoot osteoarthritis between obese and non-obese patients (BMI 30)[9].

Operative Management

Surgical options divide naturally between the medial and central columns (first, second and third TMTJs), where arthrodesis is the mainstay, and the mobile lateral column (fourth and fifth TMTJs), where motion-preserving procedures are generally preferred. Fixation options for fusion include plates, screws and staples, with or without bone graft.

Arthrodesis of the First, Second and Third TMTJs

The literature specific to isolated arthrodesis of the medial and central columns for arthritis is limited, being confounded by studies of Lapidus fusion for hallux valgus and pes planus, and fusion for Lisfranc injuries in acute trauma. Four representative studies were reviewed. Biddinger et al. (1996) reported 32 cases treated with rigid internal fixation, with one non-union, two malunions, three cases of neuritis and one superficial infection, and a significant improvement in AOFAS score.10 Sangeorzan et al. (1990) reported 16 patients with 49 joints fused for post-Lisfranc osteoarthritis, with four joints failing to unite (an 8% non-union rate, but occurring in three of sixteen patients - a 19% patient-level revision rate), 69% good or excellent results, and accurate reduction correlating positively with outcome[11]. Buda et al. (2018) reviewed 88 patients (189 joints) with an overall non-union rate of 11.4% and identified independent risk factors for non-union: the use of plate and screws without a separate lag screw, perioperative smoking, non-anatomic alignment and the absence of bone graft[12]. Nemec et al. (2011) reported 104 feet undergoing midfoot fusion with 8 non-unions and 1 delayed union, three deep infections and one case of complex regional pain syndrome, improved pain and AOFAS scores, 90% satisfaction and 26 hardware removals[13].

Arthrodesis of the Fourth and Fifth TMTJs

The mobile lateral column presents a genuine dilemma. Fusion of the fourth and fifth TMTJs risks non-union, chronic pain and stress fracture (Kurup et al., 2020), which has led to interest in motion-sparing procedures — soft-tissue or ceramic interposition[14]. The evidence, however, is contradictory. Raikin and Schon (2003) retrospectively reviewed 28 feet, of which six were fused for painful fourth/fifth-TMTJ osteoarthritis in normosensate feet and the remainder as part of neuropathic reconstruction; at two years, 26 of 28 had fused and pain scores in the arthritic group fell from 8.2 to 2.4 out of 10[15]. Another study from the same hospital subsequently performed a cadaveric study of plantar pressures showing no difference between the intact foot and medial-column (first-to-third TMTJ) fusion, but a significant increase in forefoot and calcaneocuboid pressures when the medial and lateral columns were fused together — concluding that it may be advisable to avoid fusion of the lateral column[16]. A further series of 37 patients undergoing fourth/fifth-TMTJ arthrodesis (only four in isolation, 33 combined with other midfoot fusions) reported 10.8% requiring revision for non-union but 89% overall satisfaction with significantly reduced pain scores[17].

Interposition and Ceramic Arthroplasty

Motion-preserving alternatives for the lateral column have been reported only in small series. Tendon interposition arthroplasty was described in a case report of three patients with no complications and improved pain scores (Mirmiran and Hembree, 2002)[18]. Retrospective review of 12 patients who underwent tendon interposition arthroplasty over eight years, using a slip of peroneus tertius or brevis resected from its insertion and folded into the joint, had a mean follow-up of 25 months, improved AOFAS and VAS scores, pain reduced by a mean of 35%, disability improved by a mean of 10%, and six of eight patients who participated in the study satisfied[19].

Ceramic (spherical) interposition arthroplasty using the Orthosphere® (Wright Medical) - a ceramic ball originally designed for the thumb carpometacarpal joint - was reported in 13 cases (Shawen et al., 2007): at a mean of 34 months (two lost to follow-up) all 11 remaining patients were satisfied and would undergo the same procedure again, with VAS improved by 42% and AOFAS by 87%, although one implant subsided into the cuboid and no further results were published thereafter[20]. A single 14-year follow-up of the ceramic implant described a patient cycling 25-50 miles per week and hiking regularly without pain or instability[21].

These are, however, small and uncontrolled series, and the ceramic device is noted in the wider literature to fail.

Summary

- The second and third TMTJs are the least mobile and bear most load, which may explain their predilection for non-traumatic arthritis; the fourth and fifth are mobile and functionally important.
- Oral (not topical) analgesia, image-guided injections, and full-length orthoses are supported for non-operative management of TMT Arthritis.
- Fusion of the mobile lateral column is generally best avoided because it increases forefoot and lateral load; motion-sparing interposition procedures are described but rest on small, uncontrolled series.

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Consensus Questions

Lisfranc Injuries

1. All midfoot pain with a history of trauma should be referred from the emergency department or urgent care for weight-bearing views.
   a. Yes 20
   b. No 0

2. Should all patients with a suspected Lisfranc injury have weight-bearing views, where the patient is able?
   a. Yes 20
   b. No 0

3. Where there is doubt over the diagnosis, it is recommended to perform comparative views of the contralateral side.
   a. Yes 20
   b. No 0

4. Should every Lisfranc injury have CT as part of the assessment?
   a. Yes 16
   b. No 4

5. In a stable Lisfranc injury there is a role for non-operative management.
   a. Yes 20
   b. No 0

6. Due to the heterogeneity of Lisfranc injuries, each case needs to be treated on a case-by-case, 'à la carte' basis, including both operative and non-operative management.
   a. Yes 20
   b. No 0

7. Is there a role for routine removal of hardware following Lisfranc fixation in all patients?
   a. Yes 2
   b. No 18

8. When bridging the first ray tarsometatarsal joint for Lisfranc fixation, would you routinely later remove the metalwork?
   a. Yes 10
   b. No 9
   c. Abstain 1

9. When treating a purely ligamentous Lisfranc injury surgically in a young, high-level sportsperson, would you routinely fix or fuse?
   a. Routinely Fix 11
   b. Routinely Fuse 2
   c. Abstain 7

10. In a low-demand patient with a purely ligamentous Lisfranc injury, would you routinely fix or fuse?
    a. Routinely Fix 11
    b. Routinely Fuse 8
    c. Abstain 1

11. In a subtle Lisfranc injury with less than 2mm diastasis treated non-operatively, what would your weight-bearing regimen be?
    a. Weight-bearing from day 1 with vigilant follow-up 12
    b. Non-weight-bearing for 2 weeks then gradual progression 0
    c. Non-weight-bearing for 6 weeks or more 8

12. In an operatively treated Lisfranc injury, when would you routinely allow weight-bearing?
    a. From day 1 2
    b. From 2 weeks 6
    c. Non-weight-bearing for 6 weeks 12

Tarsometatarsal Joint Arthritis

1. Should MRI be routinely used in the investigation of tarsometatarsal arthritis?
   a. Yes 8
   b. No 12

2. Routinely offer selected joint injections for tarsometatarsal arthritis?
   a. Yes 17
   b. No 3

3. Would you use SPECT-CT routinely in the investigation of tarsometatarsal arthritis?
   a. Yes 0
   b. No 20

4. Who routinely uses bone graft when performing tarsometatarsal joint fusion?
   a. Always 9
   b. Sometimes 10
   c. Never 1

5. In isolated first tarsometatarsal osteoarthritis, would you routinely fuse the first tarsometatarsal joint in isolation?
   a. Yes 20
   b. No 0

6. Where the second or third tarsometatarsal joint is affected in isolation, would you routinely fuse that joint alone?
   a. In isolation 15
   b. Fuse both 4
   c. Abstain 1

7. Who would never fuse the fourth and fifth tarsometatarsal joints?
   a. Never 15
   b. On occasion 4
   c. Abstain 1

8. Who would consider an interposition procedure for fourth and fifth tarsometatarsal osteoarthritis?
   a. Yes 19
   b. Abstain 1

9. For tarsometatarsal fusion, how do you routinely prepare the joint?
   a. Osteotome, open preparation 17
   b. Burr/MIS: 3

Session 5: The Midfoot

Chaired by Anand Pillain

5.1. Navicular Stress Fracture

Rupinder Deol

Epidemiology

- Navicular stress fractures are rare but disproportionately represented in the athletic population, particularly endurance athletes. Whilst they can be picked up early on MRI scans they are often misdiagnosed with a reported average time to diagnosis of 9 months(1). They are associated with Relative Energy Deficiency in Sport (RED-S) and should be considered as a differential diagnosis in elite athletes presenting with mid-foot pain.

Bone Anatomy and Biomechanics

- The navicula sits within a high stress zone in the medial column of the foot and is subject to substantial medial column compressive forces. It represents a critical cornerstone of the medial longitudinal arch, articulating with the talus and providing the insertion for the tibialis posterior tendon on its medial border.

- Cavus foot deformity leads to increased medial column load, resulting in a higher incidence of navicular stress fractures(2). The blood supply to the navicula is from the dorsal pedal artery laterally and the posterior tibial artery on the medial side, leaving a central watershed area where stress fractures are more likely to occur.

Mechanism of Injury and Risk Factors

- Navicular stress fractures are a true overuse injury secondary to excessive loading of the midfoot without adequate recovery. Intrinsic patient related risk factors include foot shape, joint mobility and underlying biology.

- Cavus deformity, metatarsus adductus or a short first ray can increase load on the medial column as well as gastrocnemius tightness. Stiffness of the hindfoot can lead to increased load being translated through the midfoot. Underlying RED-S or vitamin D deficiency can affect the underlying bone integrity and ability to heal after injury.

- Extrinsic risk factors include training surfaces, choice of foot wear and excessive training regimens.

Clinical Presentation and Examination

- Patients commonly present with vague midfoot pain which is exacerbated with activity(3). They may describe pain with sprinting or jumping activities. Pain will be relieved with rest and recurs with loading. ‘N-spot’ tenderness with palpation of the navicula itself is a critical sign(4). This is located between tibialis anterior and extensor hallucis longus on the dorsum of the midfoot. Asking the patient to hop may elicit pain. There may be predisposing features present such as cavus deformity or gastrocnemius tightness.

Imaging

- Pain film standing radiographs are recommended in the first instance however it is common for these to appear normal, particularly in the early stages. Sclerosis may become visible as a late sign with disease progression. MRI is the best early test for diagnosis, showing oedema in the first instance followed by a fracture line in later progression.
- CT is the gold standard for assessing stress fractures, defining the location of the fracture and associated cortical involvement as well as presence of sclerosis and degree of displacement. Sclerosis is recognised to be a risk factor for delayed union.

Classification

- The Torg classification was first described in 1982 classifying fractures from 1-3 based on whether the fracture was incomplete (Type 1), complete with partial sclerosis (Type 2) or complete with sclerosis and cystic changes (Type 3).
- The more recent Saxena classification is a CT based classification which considers the extent of the fracture ranging from no fracture line (Type 0.5, visible only on MRI), dorsal cortex involvement (Type 1), extending to mid-portion of navicular (Type 2) and both cortices affected extending to the plantar cortex (Type 3)(5). Modifiers to this system include presence of avascular necrosis (A), cystic changes (C) and sclerosis (S). A strength of the Saxena classification is that it predicts prognosis and is widely used in modern literature.

Non-Operative Management

- Management without surgery can be considered in type 1 and selected type 2 fractures. It consists of strict 6-8 weeks of non-weight bearing in a cast. Gradual return to normal activity is then achieved over a subsequent 12 weeks during which time bone health should be evaluated and optimised accordingly.

Surgical Management

- Operative treatment is indicated in Type 2 fractures with displacement, Type 3 fractures and in those patients for whom non-operative management has been unsuccessful. Elite athletes may benefit from early fixation of all fracture types to facilitate earlier return to sport(5). Percutaneous screw fixation is the technique of choice in type 2 or 3 fractures in the absence of cysts whilst open reduction, grafting and screw fixation may be indicated in Type 3 fractures with associated bone defects. The use of biologics has been described to aid fracture healing. Screw placement should be perpendicular to the fracture line and avoid violation of the talonavicular joint.
- Following surgery it is recommended that patients remain non-weight bearing for 4-6 weeks and should expect to return to sport within 4-6 months (although average return to sport has been reported as early as 10-14 weeks post-surgery)(6). Return to weight-bearing is based on radiological evidence of union. The use of radiographs at 6 weeks is common-place however CT imaging has been recommended at 6-8 weeks as a superior modality to assess union.

Surgical Outcomes

- A meta-analysis by Attia et al. (2021) of 315 fractures, predominantly in competitive athletes, reported operative success in 97.9% of cases with consistently higher union rates and return to sport than non-operative treatment(7). Non-operative success was reported as 78.1% with wide variability in management and outcomes. Surgery was associated with faster return to sport, fewer non-unions and a lower re-fracture rate.
- Delayed diagnosis was strongly associated with poorer outcomes. Operative fixation was recommended for high-demand athletes requiring a predictable outcome including union and timely return to sport.

Summary

- Navicular stress fractures are a high risk injury that can be easily missed. Late diagnosis has an adverse impact on overall outcomes and early imaging with MRI should be considered in athletic patients presenting with midfoot pain.
- Type 1 injuries can be managed with non-operative management with strict non-weight bearing protocols for a minimum of 6 weeks.
- Surgery is indicated for type 2 and 3 injuries in the form of percutaneous screw fixation or open fixation and bone grafting. Early surgery improves time to return to sport and should be considered in high-demand athletes.

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Consensus Questions

1. MRI is the recommended imaging modality for a suspected navicular stress fracture in the context of a normal radiograph.
   a. Yes 18 (95%)
   b. No 1 (5.3%)
2. A period of 6 weeks non-weight bearing is recommended for non-operatively managed navicular stress fractures.
   a. Yes 17 (89.5%)
   b. Abstain 1 (5.3%)
   c. No 1 (5.3%)
3. Early surgical fixation is indicated for elite athletes with type 2 and 3 navicular stress fractures.
   a. Yes 17 (89.5%)
   b. Abstain 2 (10.5%)
4. Following both operative and non-operative management of type 2 and 3 navicular stress fractures, should you routinely perform CT imaging to assess healing and inform rehabilitation?
   a. Yes 11 (58%)
   b. No 2 (10.5%)
   c. Abstain 6 (31.6%)
5. In an athletic individual with a Type 1 navicular stress fracture when would you advise realistic return to impact sports?
   a. At six weeks 0
   b. At twelve weeks 16 (84.2%)
   c. Beyond twelve weeks 2 (10.5%)
   d. Abstain 1 (5.3%)

5.2. Midfoot Charcot: pathology, biomechanics and current controversies in reconstruction

Anand Pillai

Pathophysiology and the Mechanics of Collapse

Two mechanisms, one cascade[1,2,3,4]

Two mechanisms have long been proposed for Charcot neuroarthropathy. The neurovascular theory holds that autonomic dysfunction produces hyperaemia and arteriovenous shunting, leaching bone from the foot and leaving it weak enough to fail under an ordinary load. The neurotraumatic theory holds that the loss of protective sensation allows repetitive microtrauma to continue unchecked. In clinical practice the two operate together rather than in competition. The patients who develop the condition are those with several years of diabetes and established peripheral neuropathy, and the affected limb is characteristically relatively well perfused, warm and often frankly hot.[1,2,3]

Both routes converge on a single inflammatory process. Tumour necrosis factor alpha, interleukin-1 beta and interleukin-6 upregulate RANKL; rising RANKL with falling osteoprotegerin drives an osteoclast surge, and bone is resorbed faster than it can consolidate.[1,2,4]

The consequences are osteopenia, fragmentation, fracture, subluxation and ligamentous laxity, with weakening not only of bone but of the tendons and muscles that depend on it, and with them the loss of the architecture of the foot.[2,4] Because pain is blunted throughout, the inflammatory phase is recognised late; and because the resulting deformity increases both load and shear across an already failing midfoot, the cascade feeds itself. This self-amplifying character is the single most important feature of the disease to grasp, and it is summarised in Figure 1.

Figure 1. Two Mechanistic Theories Converge on One Self-Amplifying Cascade

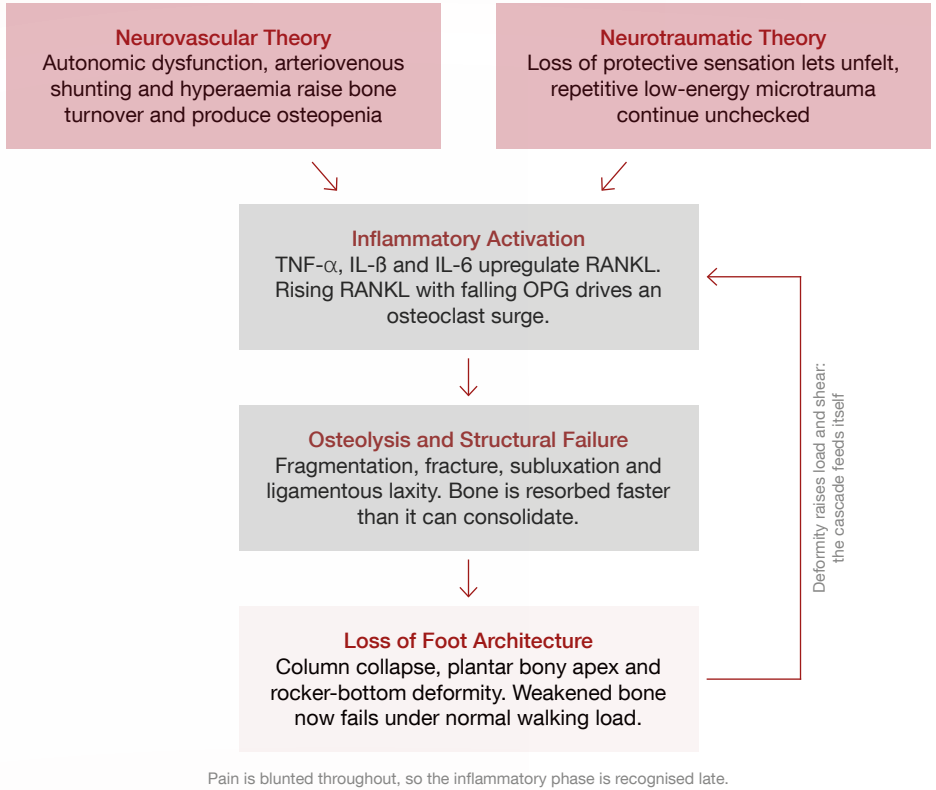


Figure 1 - The neurovascular and neurotraumatic theories converge on a single self-amplifying inflammatory cascade.

Equinus as the Dominant Deforming Force[2,3]

In the midfoot the principal deforming force is generally held to be the gastrocnemius – soleus complex/Achilles tendon. Glycosylation of collagen over years of diabetes alters the structure of the Achilles tendon and of the surrounding muscle, so that the tendon does not yield as a normal tendon would. Due to the size and strength of the Achilles tendon's pull, an uneven or shortened Achilles becomes one of the major drivers of the rocker-bottom foot.

The mechanism is a lever-arm problem. A short Achilles complex produces hindfoot equinus and an earlier heel rise during gait; the forefoot is therefore loaded earlier and for longer, the effective lever arm across the midfoot lengthens, and the bending moment applied to a midfoot already compromised by the Charcot process rises. Sensory loss removes the signal that would ordinarily limit this repetitive axial and shear loading, while osteopenic trabeculae and lax ligaments lower the load at which failure occurs. Collapse follows when repeated load multiplied by lever arm exceeds the residual structural stiffness of the softened midfoot.

Deformity in Three Planes[3,5]

Although the topic is conventionally described as the mechanics of the rocker-bottom foot, the deformity is not a simple sagittal collapse but a three-dimensional one and recognising this is important from a surgical perspective. Correction is rarely reliable in every plane at once, and much of the time the operative aim is to reconstruct a plantigrade weight-bearing surface rather than to restore the foot to the shape it had before it collapsed.

In the sagittal plane there is equinus at the back of the heel and collapse of the arch, driven principally by the tight Achilles complex that will not yield.
In the coronal plane there is hindfoot varus or valgus, depending on the direction the heel takes, which shifts talar moments and determines which joints fail first.
In the transverse plane there is forefoot abduction or, less often, adduction.

The transverse component deserves particular emphasis. It is not the plantar apex alone that causes point loading; once there is forefoot rotation, shear forces are generated instead of compression across the apex of the deformity as the patient walks, and it is shear that leads to ulceration. The clinical observation offered was that patients with a rocker-bottom foot whose toes remain reasonably aligned often accommodate well in orthopaedic footwear and rarely ulcerate. Once forefoot abduction develops, the foot begins to shear, breaks down, is offloaded, heals, and then breaks down again when surgical shoes are resumed.

Figure 2. Deforming Forces Act in Three Planes

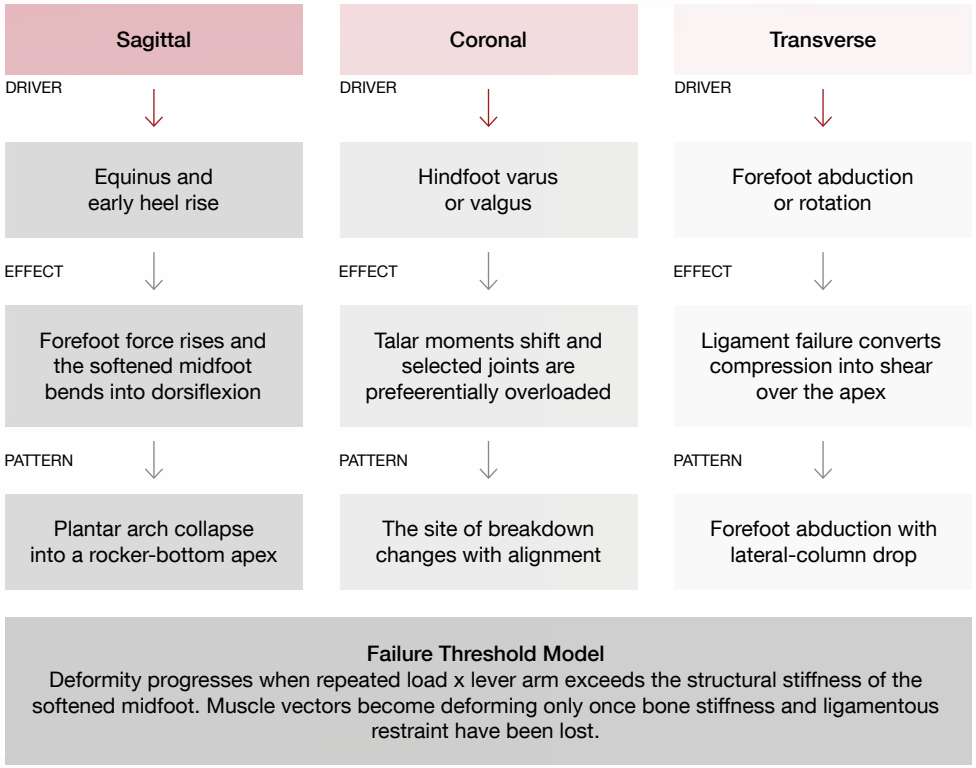


Figure 2 - Deforming forces in the sagittal, coronal and transverse planes, with the driver, effect and resulting deformity pattern in each.

Muscle Imbalance and Column-Specific Failure[2,3]

Motor neuropathy, intrinsic wasting and Achilles stiffness convert what are normally balanced muscle vectors into deforming forces. Loss of the intrinsic muscles affects the longitudinal arch and toe stabilisers, producing the claw toes and abolishing the windlass mechanism. Around the midfoot itself there is a medial tendon bias: tibialis posterior and tibialis anterior attach medially and add inversion, adduction and medial rotation at the naviculocuneiform and tarsometatarsal joints, while the peroneals attach laterally and accentuate forefoot abduction and lateral-column shear once ligamentous restraint has failed.

The important qualification is that these muscle vectors become deforming only after bone stiffness and ligamentous restraint have already been lost.

Where the disease begins medially and the medial column collapses, tibialis anterior and posterior no longer function effectively and the peroneals pull the foot laterally, producing a medial prominence that ulcerates under shear.

Where the Chopart joint fails, the strong medial tendons pull the whole foot dorsally while the equinus force pushes the talus and calcaneus into the floor, and the prominence that forms is central or slightly lateral, usually at the cuboid.

Where the lateral column is primarily affected, the medial tendons draw the foot into adduction and it is the cuboid that becomes prominent.
These lateral patterns are the most difficult to treat, because the cuboid cannot simply be resected without destabilising the foot.

The Column Failure Sequence and the Plantar Apex[2,3,6]

Rocker-bottom deformity develops through a recognisable sequence of column failure. Early instability begins in the medial column, most often at the naviculocuneiform or tarsometatarsal joints, and longitudinal arch support weakens. The arch then collapses plantarward, with the talar head and midfoot migrating plantarly while the forefoot abducts or rotates. The mechanical inflection comes when the lateral column drops: cuboid height falling below the weight-bearing axis is the negative prognostic marker for callus and ulceration, and it is at this point that the plantar apex is created.

Once the apex becomes the new sole, soft tissue must carry load that was formerly distributed across the whole arch. Sagittal collapse lowers the longitudinal arch, forefoot abduction and rotation add shear over the apex, and the combination produces the focal high pressure that leads to ulceration.

Recognition, Staging and Classification

The Hot Swollen Foot[1,2,4]

Active Charcot is frequently less painful than its appearance suggests.
The acute presentation is a unilateral red, hot, swollen foot in which pain is absent or mild despite impressive swelling, pulses are often preserved or bounding, and any trauma may have been trivial or not recalled at all.
The chronic, established presentation is quite different: midfoot collapse with rocker-bottom convexity, forefoot abduction or rotation, callus over the plantar bony apex, and recurrent ulceration or infection following the pressure.

The orthopaedic red flag is straightforward. Diabetes with neuropathy and new warmth or swelling is sufficient reason to immobilise while investigating.
The instruction is to treat the foot as active Charcot until proven otherwise, and not to wait for a dramatic radiograph.

Examination and the Trigger to Act[2,4]

Neuropathy should be demonstrated with a Semmes-Weinstein monofilament and a 128Hz tuning fork for loss of pressure and vibration sense.
The skin envelope should be inspected for ulcer, callus, sinus, blistering or threatened skin over the plantar apex. Stability should be assessed - arch collapse, midfoot laxity, forefoot abduction, and whether the foot can safely be braced - and pulses should be documented, since vascular disease changes both risk and treatment. Erythema that reduces on elevation supports Charcot rather than infection. A temperature difference greater than 2°C between the two feet supports active disease.

Where active Charcot is plausible, the immediate action is to immobilise or offload, image, and refer to a diabetic foot multidisciplinary team; the guiding rule is to protect first and investigate in parallel.

Differential Diagnosis[1,2,4]

Cellulitis, osteomyelitis, gout, deep vein thrombosis and simple sprain or fracture all mimic acute Charcot, and several of them can coexist with it. Charcot is the more likely diagnosis in a neuropathic foot with warmth and swelling, mild or no pain, erythema that improves with elevation, and multi-joint midfoot involvement. Infection is the more likely diagnosis where there is an ulcer or sinus, where bone can be probed, where there is systemic upset with rising inflammatory markers, or where imaging shows focal bone involvement or abscess.

Three practical decision points follow. Where there is no ulcer but a hot midfoot in a neuropathic patient, the foot should be treated as active Charcot and offloaded while imaging confirms stage and extent. Where there is an ulcer, a sinus or systemic markers, possible osteomyelitis must be assumed until excluded, with urgent multidisciplinary review and an infection work-up. Where the diagnosis remains unclear, the foot should be immobilised and reassessed, with MRI or nuclear imaging used to help distinguish active Charcot from infection.

Imaging[2,4]

Active Charcot is a clinical diagnosis supported by imaging rather than a radiological one. Weight-bearing radiographs are the first-line investigation and are used to assess collapse, subluxation, debris and alignment; the classical radiographic features are summarised as the five Ds - distension, dislocation, debris, disorganisation and density. Where the radiograph is equivocal, MRI detects marrow oedema and is particularly useful in stage 0 disease, while nuclear imaging can help where infection is suspected.

Eichenholtz staging[2,4]

The Eichenholtz stages explain when the mechanics are most dangerous.

Stage 0, the prodromal stage, is a hot swollen foot in which radiographs can be normal and MRI may show marrow oedema; this is particularly important because deformity can still be prevented at this stage.

Stage I, fragmentation, brings osteopenia, fractures, debris, subluxation and ligamentous laxity, and it is here that the deformity forms.

Stage II, coalescence, is marked by falling warmth, absorption of debris and the appearance of sclerosis and early fusion.

Stage III, consolidation, leaves a quiescent foot with fixed deformity, arthrosis and remodelling.

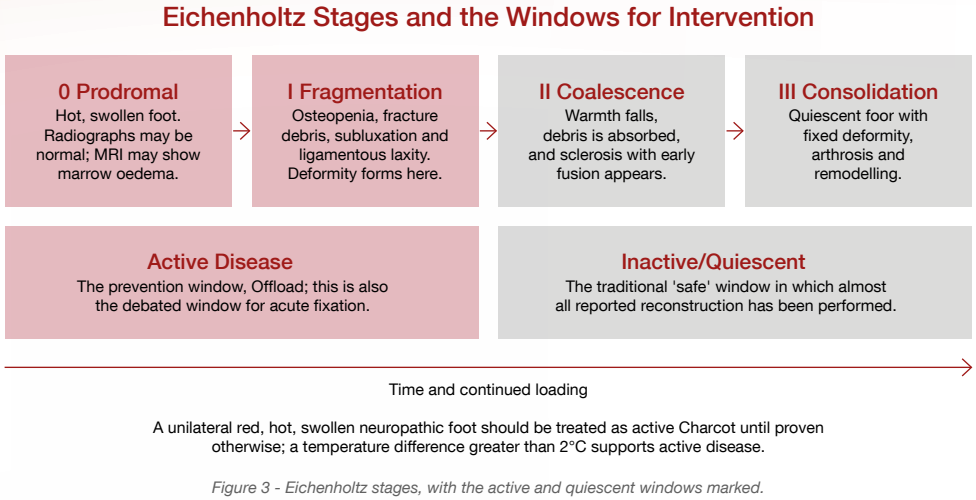


Figure 3 - Eichenholtz stages, with the active and quiescent windows marked.

Classifications

Several classifications are in use, and they answer different questions.

The Sanders and Frykberg classification[7] describes which anatomical zones are affected.

I. Forefoot
II. Lisfranc (Tarsometatarsal) joint, Most common ~45%
III. Midtarsal joint including naviculocuneiform ~ 35%
IV. Ankle and subtalar joints
V. “Posterior Pillar” fractures of the calcaneus

The Brodsky classification[8] is another anatomical classification separating the foot into zones.

Type 1, midfoot, comprising the tarsometatarsal (Lisfranc) and naviculocuneiform joints representing the commonest site.
Type 2, hindfoot, comprising the subtalar and Chopart joints
Type 3, the ankle (3A) or the calcaneus (3B).

The Kavarthapu and Vris classification[9] describes how the foot deforms and recognises three structural patterns on weight-bearing radiographs:

1. Rocker-bottom with forefoot abduction, which is the commonest;
2. Dorsal subluxation or dislocation; and
3. Forefoot adduction, which is the least common.

The Schon classification[10,11] adds a further dimension by mapping the apex of collapse and grading its severity.

Type I lies at the metatarsocuneiform joint medially and the metatarsocuboid joints on the lateral side with a medial or plantar-medial prominence
Type II at the naviculocuneiform joint medially and the metatarsocuboid joints on the lateral side, giving a plantar-lateral prominence
Type III in the perinavicular region, with a plantar-central or lateral prominence
Type IV at the transverse tarsal joints, with variable prominence and direction of deformity.

Stage A describes a midtarsus lying above the plane, stage B a coplanar midtarsus, and stage C a midtarsus below the plane - which is the rocker-bottom foot at risk of ulceration because it is now prominent.

The anatomical classifications are useful as research tools rather than as guides to treatment and are of limited practical use. What does matter is pattern recognition: the deformity apex and the columns involved determine how far the reconstruction must extend.

Current Controversies in Charcot Reconstruction

In the field of Charcot reconstruction literature is scarce. There are no randomised trial. Most of the evidence is level four - case series - and what evidence does exist comes from only a few centres around the world who perform high volumes of these procedures.[12,13]

Why the Midfoot Matters, and Why it is Hard to Fix[12,13]

Once the midfoot collapses, the loss of architecture and the resorption of bone by the inflammatory process leave a new sole on the foot, usually formed by the cuboid or the middle cuneiform depending on the pattern. Combine that with forefoot abduction and the shear forces it generates and ulceration follows; point loading produces an ulcer, which progresses to osteomyelitis, leading to chronic infections and amputation.

The difficulty of fixing it has several components; bone quality is poor, patients are neuropathic, which means both that they are insensate and that they are unlikely to be reliably compliant. Blood supply in the Charcot situation is generally reasonable but by no means normal. Infection and wound-healing risk are high, because these patients are also immunocompromised: an infection that could be managed with antibiotics in another individual behaves differently here, because there is some degree of tissue ischaemia in addition to immune compromise, and the infection is not fought off in the same way.

Finally, it is not one joint that is being fused: the deformity spans several joints, and even where the midfoot is successfully brought together the hindfoot may subsequently collapse.

Against this, the goals of reconstruction are the same whichever technique is used, and the debate is only about how best to reach them. The aim is a plantigrade foot that loads evenly and can be braced; a foot free of ulceration and infection; stable alignment without loading points that will break the skin down later; functional ambulation, because keeping patients walking maintains their physiology and their survival; limb preservation, since mortality climbs steeply after amputation; and a durable result that minimises reoperation, metalwork failure and recurrent collapse.

Question 1. Operate at all - Cast it or Cut it?[12,13,46]

Conservative care remains first-line and works in most cases, so the real question is which feet justify the risk of surgery. Total contact casting reduces plantar pressure, allows midfoot ulcers to heal, and avoids the high wound and infection risk of operating on a neuropathic and often dysvascular foot; its costs are prolonged immobilisation, recurrent casting, and the risk of progressive deformity if the arch continues to collapse.

Surgical reconstruction is reserved for unbraceable deformity, for recurrent or non-healing ulceration, for instability, and for osteomyelitis; it aims to restore alignment so that the foot can be braced and ulcers stay healed, and it is increasingly accepted for severe deformity, but it carries substantial complication rates.

Surgery is therefore a selective tool for feet that conservative care cannot keep plantigrade and ulcer-free, and not a default. Part of the controversy is one of thresholds: there is no agreed trigger for converting from cast to knife.

Total Contact Casting Against Removable Offloading[14]

A systematic review and meta-analysis comparing total contact casting with removable offloading found that the contact cast performed better on the outcomes that matter most: higher rates of ulcer healing and a shorter time to heal, when compared against removable walking casts and footwear.
The trade-off is that it was associated with a higher rate of complications, so patients must be selected carefully and the skin monitored closely.

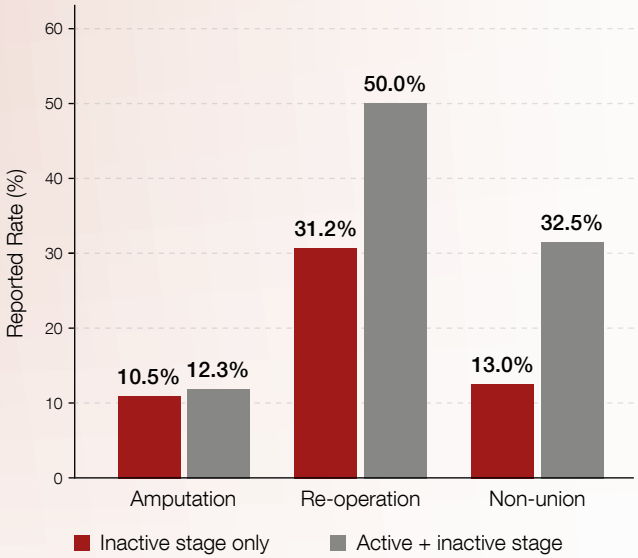
Question 2. When to Operate - Hot Foot or Cold Foot?

Classical teaching defers surgery to stage III, the consolidation phase, on the grounds that operating on a consolidated and quiescent foot lowers infection and hardware-failure risk and gives more reliable fusion. The counterargument is that waiting risks a fixed deformity, and that intervening before collapse may preserve a reconstructable foot - at the price of operating on a hot, fragile limb with higher early complications.[12,13]

There is no high-level evidence identifying the optimal window, and practice is largely surgeon dependent.

A systematic review of seventeen studies examined surgical timing.[15] No study in that review reported operating in the active stage alone, so the comparison available is between surgery performed in the inactive stage and surgery performed in a mixture of active and inactive stages. Amputation was reported at 10.5 per cent in the inactive-stage group against 12.3 per cent in the mixed group; re-operation at 31.2 per cent against 50.0 per cent; and non-union at 13.0 per cent against 32.5 per cent.[15] Operating on the quiescent foot therefore trended towards fewer re-operations and non-unions.

Outcome by Stage at which Reconstruction was Performed



Data: Tan & Chua, systematic review of 17 studies. No study reported surgery in the active stage alone.

Figure 4. Outcomes by the stage at which reconstruction was performed.

Question 3. Revascularise First?

Charcot neuroarthropathy and peripheral arterial disease frequently coexist, and healing a fusion or a surgical wound demands inflow. Clinical examination depending on distal pulses' palpation under-detect arterial disease, so a low threshold for angiography is reasonable, and where ischaemia is identified it should be corrected first, with staged endovascular or open revascularisation preceding elective reconstruction. In diabetic Charcot reconstruction, peripheral arterial disease diagnosed by angiography rather than by clinical examination alone was associated with faster return to ambulation and with a trend towards fewer major amputations, which argues for objective vascular work-up in the pathway.[16]

Question 4. Correcting Equinus: Gastrocnemius Recession or Tendo-Achilles Lengthening?[17,18]

Equinus raises forefoot and midfoot plantar pressure and is implicated both in ulceration and in Charcot collapse. Achilles lengthening combined with casting healed more diabetic plantar ulcers and reduced two-year recurrence when compared with casting alone.[18] Two procedures are available and the choice between them is guided by the Silfverskiöld test.

Gastrocnemius recession targets isolated gastrocnemius contracture, it is performed when the Silfverskiöld test is positive; it preserves more push-off strength and carries a lower risk of over-lengthening and transfer ulceration than tendo-achilles lengthening.

Tendo-Achilles lengthening is used for combined gastrocnemius–soleus equinus, and percutaneous triple hemisection offers a quick and powerful correction, but over-lengthening risks weakness and heel ulceration.

Question 5. Just Shave the Bump — Exostectomy?[19,20]

For a stable foot with a single plantar prominence, the question is whether resection alone is enough without a major fusion. Exostectomy is non-reconstructive debulking of the plantar prominence, and it is a well-established approach in patients with a plantar bump at risk of ulceration. In the reported series, 60 per cent of ulcers healed after the first exostectomy, with cumulative success reaching 90.7 per cent across repeat procedures. It is best suited to the stable, focal prominence; failures climb when the indication is stretched.

Medial exostectomy, generally tends to work well with uniformly good outcomes. Lateral-column resection carries higher and more varied complications. Exostectomy is of no use for gross instability, and over-resection destabilises the foot.

Question 6. Beams and Superconstructs — How Far to Fuse?[13,21,22,23,46]

Intramedullary beaming is the workhorse of midfoot realignment. The beams resemble large cannulated screws but are considerably stronger, and some are now solid core.

The "Superconstruct" principle: extend the fusion beyond the zone of injury; resect bone to reduce the deformity without skin tension; use stronger, often Charcot-specific implants; and position the devices so that they are load-sharing.[13,46]

Beaming restores a plantigrade, ulcer-free foot in approximately 80 to 84 per cent of cases, but deep infection, hardware failure and non-union are common, and a systematic review rated the quality of the underlying studies as poor.

In the beaming series most often quoted by Ford et al, 84 per cent achieved an ulcer-free, stable, plantigrade foot; deep infection occurred in 24 per cent, and every patient who developed deep infection had had a pre-operative ulcer; 16 per cent progressed to amputation, all for deep infection.[21]

A systematic review by Ong et al[23] found that:

1. cannulated screws showed 39 per cent higher risk of breakage against solid-core implants with weight bearing
2. A solitary midfoot bolt is at risk of axial migration is used for medial column stabilisation without preparing joint surfaces
3. A single implant is biomechanically insufficient because it becomes a centre of rotation and permits rotational instability.

The failure pathway for a beam used alone follows a recognisable sequence: cyclic load produces micromotion, loss of correction, non-union and the need for revision.

It presents in three ways. Breakage is fatigue fracture after repetitive load, particularly when the beam is the only column resisting motion. Loss in position is migration, loosening or rotational drift. Failure to heal is persistent micromotion across the arthrodesis leading to delayed union or non-union. Across series, breakage and hardware fatigue are reported at 11 to 39 per cent and non-union or absent radiographic union at 17 to 57 per cent, although definitions and follow-up vary considerably.[21,23]

MBPC/Midfoot Beam Plate Construct

Beams alone maintain column length with less exposure than plate fixation; adding a plate provides a buttress and rotational control while the beam maintains length. In the beaming series, 84 per cent achieved a stable, plantigrade, ulcer-free foot but only 46 per cent showed radiographic bony union.

In a medial beam-plate construct cohort of 41 limbs, 94 per cent of pre-operative ulcers healed, and new or recurrent ulceration occurred in 46 per cent; a figure of 68 per cent was reported for a plantigrade, shoeable, ulcer-free result.[24] These are separate cohorts rather than a controlled comparison, and the sensible reading is that plates are a stability tool rather than a universal upgrade. Beams alone suit a stable soft-tissue envelope with multi-column beaming and a deformity reducible without a large buttress; the addition of a plate suits severe abduction or rocker-bottom deformity, rotational instability, medial column collapse, or a correction requiring buttress support.

A further question is whether to include the subtalar joint. Adding subtalar arthrodesis to the beam was linked to approximately 80 per cent fewer complications in one series and to less progression to hindfoot Charcot and a greater number of screws correlated with fewer failures.[25,26]

Question 7. Which Joints and Columns to Fuse?

Medial-column fusion realigns the main weight-bearing axis; adding the lateral column improves the stability of the whole midfoot but means more dissection in fragile tissue. The workhorse operation is resection and realignment arthrodesis, in which a wedge resection through the apex restores the arch and shortens the lever, and rigid arthrodesis then holds the correction.12,13 The governing principle is to fuse far enough to bridge the unstable zone of injury, but no further than the soft tissues will tolerate.

Question 8. Internal or External Fixation?

A systematic review compared internal against external fixation and reported odds ratios with internal fixation, taking external fixation as the reference.27 Internal fixation was associated with more return to ambulation (odds ratio 1.26), substantially less non-union (0.12) and lower ulcer occurrence (0.58), but with approximately twice the deep infection (2.07) and around three and a half times the wound problems (3.41).[27] Internal fixation therefore offers better union, better fusion rates and a more reliably stable foot for ambulation, at a higher soft-tissue and infection cost; external fixation suits the actively infected foot and the poor soft-tissue envelope. No consensus best construct exists.

The current direction of thought is to combine the two: internal fixation such as beams provides the rigid arthrodesis construct, and an external frame adds rotational control, offloads the construct, protects fragile, infected or poorly vascularised soft tissue, and allows the patient a degree of immediate mobility with better compliance. A retrospective series of 22 patients using combined fixation achieved limb salvage in 90.9 per cent, 20 of 22 limbs; but pin-tract infection occurred in 45 per cent, superficial wound infection in 41 per cent and wound dehiscence in 36 per cent, and 2 of the 22 still progressed to below-knee amputation.[28] Combined fixation improves salvage in the complex, infected or poor-bone foot but carries a high wound and pin-site burden, and should be reserved for selected cases. No strong evidence favours any single fixation modality, and no randomised studies exist.[13]

Question 9. Midfoot Alone, or Extend into the Hindfoot?

The case for extending the construct across the subtalar joint rests on the association between adding subtalar arthrodesis and approximately 80 per cent fewer complications in one series, on less progression to hindfoot and ankle Charcot, and on the correlation between more screws or a longer construct and fewer failures.[25,26] The case for restraint is that it sacrifices hindfoot motion that may not need to be sacrificed, that it means a longer operation with more dissection and more hardware in poor bone, that it is not done consistently, and that the evidence is retrospective only.[25,26]

Where the deformity does span both regions, a single-surgeon series from Kavarthapu et al reported on 34 patients and 35 feet treated between 2009 and 2019.[29] 33 of 35 feet were fully weight-bearing in a shoe or brace at a mean follow-up of 53 months; 11 of 13 active ulcers healed; midfoot fusion was achieved in 32 of 35 feet and hindfoot fusion in 28 of 35; metalwork failure occurred in five feet, with removal in three, and four feet required revision.[29]

To compare Najefi et al reported a 19% rate of metalwork failure in hindfoot nails.[30] Kummen et al reported 24% major hardware failure across all internal-fixation reconstructions. Hardware failure in combined hindfoot and midfoot procedures reached 56 per cent, approximately twelve times higher than in isolated midfoot or hindfoot reconstruction ($P<0.001$).[31]

Question 10. Is There a Role for Minimally Invasive Surgery?

The attraction of percutaneous correction is that it limits soft-tissue stripping and spares an envelope whose breakdown is the principal enemy, and it pairs naturally with intramedullary fixation delivered through stab incisions.[32,33] The caveats are substantial: the evidence consists mostly of technique descriptions and small series, with no comparative or randomised data; the usual risks of deep infection, hardware failure and non-union remain; and there are technique-specific risks in the form of a steep learning curve, incomplete correction, and thermal or neurovascular injury from percutaneous work.[13,32,33] Minimally invasive surgery in this setting should be positioned as emerging rather than standard.

Question 11. Is a Stable Fibrous Union Enough?

In the beaming series, only 46 per cent of midfoot osteotomies achieved radiographic bony union, yet 84 per cent achieved a stable, plantigrade, ulcer-free foot.[21] This raises the question on whether radiographic union is a prerequisite for good results if the foot is stable, plantigrade and ulcer-free. In a neuropathic foot a stable fibrous or pseudo-union can deliver the clinical goal without solid bony fusion, so radiographic non-union is not automatically a failure. The result that counts is a braceable, ulcer-free, ambulatory foot. The failures that matter are unstable non-union, hardware breakage, recurrent ulceration and deep infection - which is why the practical aim is fixation that remains stable long enough for the foot to scar in solidly.

Question 12. Salvage or Primary Amputation?

Reconstruction is now widely favoured, but amputation with prosthetic fitting is not always the worse choice, and the economic picture is closer than is often assumed.

A cost comparison at twelve months put limb salvage at 56,712 US dollars against 49,251 US dollars for transtibial amputation — broadly comparable.[34] Salvage preserves the limb and body image, many patients keep walking, reconstruction series report high limb-salvage rates of around 92 per cent, and revascularisation guided by angiography improves the odds. Primary amputation offers one definitive operation instead of multiple staged salvage procedures, may be better for severe infection, dysvascularity or frailty, and avoids prolonged non-weight-bearing and the spiral of failed salvage.

The argument that reconstruction is cost-effective over a lifetime is harder to make than it first appears, because these patients do not live long enough to realise the benefit. Five-year mortality in Charcot neuroarthropathy is reported at 29 per cent.[12] In a 151-case series, 14.6 per cent died following Charcot reconstruction, with mortality risk 3.4 times higher in the presence of peripheral arterial disease and 2.5 times higher with end-stage renal disease.[35] Diabetic foot osteomyelitis alone carries a five-year mortality of over 50 per cent.[36]

Mortality tracks systemic comorbidity rather than the foot procedure, and there is no high-quality evidence that reconstruction itself lowers mortality; its goals are limb salvage and function, and survival depends on optimising the whole patient. No randomised data exist.

Reconstruction Outcomes Overall

Pooled results give a useful sense of scale. A systematic review of studies published between January 1993 and December 2018, covering 1,116 feet in 1,089 patients, reported overall bony fusion in 86.1 per cent, return to ambulation in 91 per cent, and post-reconstruction amputation in 5.5 per cent, with technique-related complications in 36 per cent.[37] No fixation method showed clear superiority. A companion narrative review of the past decade's advances concluded that there are no randomised controlled trials and no controlled comparisons, and that while the series are promising there is no proven best modality.[13] Reconstruction can salvage selected limbs, but the results are selection-dependent, and the construct should be tailored to the deformity, the infection status, the soft tissues and the perfusion.[13,37]

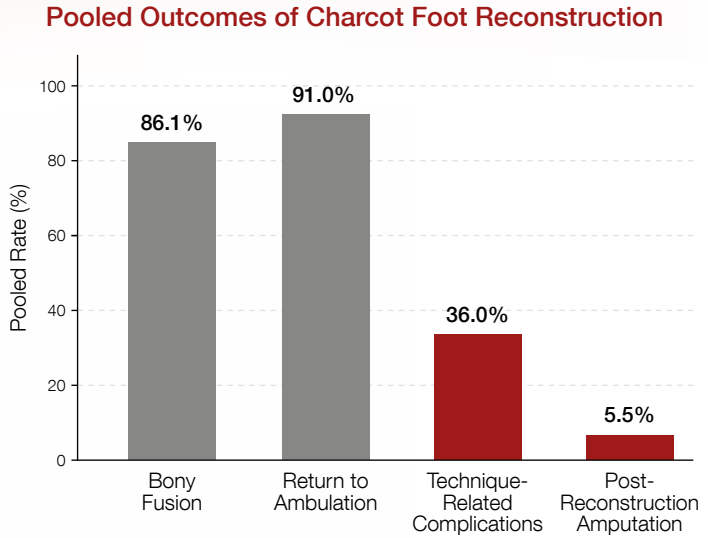


Figure 5. Pooled outcomes of Charcot foot reconstruction.[37]

Two-Stage Reconstruction in the Presence of Infection

Where infection is active, a two-stage approach is indicated. The first stage consists of radical debridement of infected bone and of the ulcer, insertion of an antibiotic-loaded calcium-sulphate bio-composite carrying gentamicin or vancomycin, temporary stabilisation with thick guide wires, and an interval course of systemic antibiotics. The second stage, undertaken once infection has cleared, corrects the deformity with long-segment rigid internal or external fixation, on the principle of combining optimal bone apposition with local antibiotic elution.[36,38]

The reported results are encouraging. In a series of 23 feet, limb salvage was 100 per cent, all ulcers had healed at one year, and fusion was achieved in 83 per cent of hindfeet and 60 per cent of midfeet, and hardware failure in five.[38] In the bio-composite series, primary ulcer resolution and limb salvage were both 100 per cent in the reconstruction group, union was 76 per cent, and the post-operative antibiotic course was shorter.[36]

Question 13. How do we Measure Success?

If pain is blunted by neuropathy, it is not obvious that standard foot scores can tell us what matters after Charcot reconstruction, and this makes the evidence base difficult to evaluate. The AOFAS score has a large pain component and is a clinician-and-patient hybrid rather than a pure patient-reported outcome measure; it is not validated for Charcot neuroarthropathy and discriminates poorly when neuropathy makes pain unreliable. The MOXFQ is a validated foot and ankle patient-reported measure but includes a pain domain, is not Charcot-specific, and its pain weighting may under-read disease burden. The DiaFootQ is a diabetic-foot measure covering lifestyle, function, footwear and self-care; it is validated for diabetic foot disease but its performance in Charcot is not yet established. The FAAM is function-focused, covering activities of daily living and sport, is less pain-dominant, has been validated broadly and used in midfoot Charcot quality-of-life, but is not widely reported.[39,40,41,42]

The recommendation is to use the FAAM-ADL if you need a functional score, but it would be imperative to report it alongside hard Charcot endpoints - plantigrade braceable foot, ulcer-free survival, ambulation, reoperation and amputation.

Question 14. Reference Centres, Training Standards and a Registry[43,44,45]

The final question is whether Charcot reconstruction is too low-volume and too high-complexity to be delivered everywhere, and who should own the outcome data. Viewed through the Getting It Right First Time 43 lens - clinically led review, benchmarking, reduction of unwarranted variation and data-driven improvement - the subject is a limb-salvage pathway rather than a single operation.

The argument for a reference-centre model is that outcomes depend on case selection, on multidisciplinary timing and on the availability of rescue options, and that planned regional referral to centres with reconstructive volume and with vascular and diabetes support is therefore defensible. The argument against it is access: travel burden, and the continuing need for local urgent offloading pathways. On training, the position taken was that surgeons should operate within an explicit scope of competence, with supervised exposure, a logbook and case review; should know when not to reconstruct, taking account of infection, perfusion, soft-tissue envelope and patient frailty; and should maintain multidisciplinary governance including morbidity review, imaging review and revision or amputation backup.

On the registry question, the conclusion was that orthopaedics cannot own it alone, since vascular surgery, diabetes medicine and podiatry shape both risk and success. A minimum dataset would include ulcer-free survival, ambulation, braceability, revision, infection, amputation and a patient-reported functional measure, using National Diabetes Foot Care Audit[44] and GIRFT logic to benchmark units and networks and to feed the results back to commissioning and training.[45] A regional reference-centre model is defensible for reconstruction, but the registry must be multidisciplinary in ownership, with shared endpoints and transparent network outcomes.

Summary

- Charcot is one self-amplifying cascade rather than two competing theories: neurovascular hyperaemia and neurotraumatic microtrauma converge on RANKL-driven osteoclastic resorption, and blunted pain allows the loop to run unchecked.
- Diagnosis is clinical and supported by imaging, not made by it. A neuropathic foot that is newly warm and swollen should be immobilised and treated as active Charcot until proven otherwise.
- Conservative care remains first-line and surgery is selective: unbraceable deformity, recurrent or non-healing ulceration, instability and osteomyelitis. There is no agreed threshold for converting from cast to knife.
- Superconstruct principles apply - fuse beyond the zone of injury, resect to reduce without skin tension, use stronger implants and position them to load-share. A single beam is biomechanically insufficient because it becomes a centre of rotation.
- Internal fixation buys union and ambulation at a soft-tissue and infection cost; external fixation suits the infected foot and the poor envelope. No modality has shown clear superiority.
- Radiographic union is not the endpoint. A stable fibrous union in a plantigrade, ulcer-free, braceable foot is a clinical success; unstable non-union, hardware breakage, recurrent ulceration and deep infection are the failures that matter
- Mortality tracks systemic comorbidity rather than the foot procedure. Reconstruction is a limb-salvage and function operation but not necessarily translating to improved survival.
- Existing foot scores are pain-weighted and poorly suited to a neuropathic population. Function-focused measures reported alongside hard endpoints - ulcer-free survival, ambulation, reoperation, amputation - and collected in a multidisciplinary registry would serve the field better.

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5.3. Non-operative management of midfoot Charcot *Kowshik Jain*

- The goals of treatment in midfoot charcot neuroarthroplasty (CN) are to create and maintain a plantigrade and ulcer free foot. Non-operative management has an essential role in managing acute and subacute phases of disease (Eichenholtz 1 & 2)(1).
- Surgery can be avoided in chronic cases with stable deformity without infection or soft tissue compromise. Furthermore many patients will not be suitable for surgical procedures due to underlying co-morbidities and therefore optimisation of non-surgical management is paramount.

Acute Phase

- In the acute phase of CN non-operative management consists primarily of immediate offloading with activity modification. Delays to diagnosis and initiation of treatment have been associated with adverse outcomes and disease progression to the destructive phase, along with a much higher rate of overall complications(2). As such, in cases where acute CN is suspected immediate treatment should be initiated(3).

Choice of Immobilisation

- Treatment of acute charcot consists of immobilisation in an offloading device. There is wide variation in device selection. Irremovable devices and techniques include Total Contact Casting as well as fibreglass augmentation of walker boots (immediate Total Contact Casting, ITCC).
- Removable orthoses include the Charcot Restraint Orthotic Walker (CROW) boot and custom made Ankle Foot Orthoses. Irremovable devices have the advantage of improved compliance and have been found to reduce the median time to episode resolution by 3 months in comparison with removable devices(4).

Weight-Bearing

- There is currently no evidence to suggest that weight bearing compromises recovery in acute CN. A systematic review by Prem et al. reported that allowing weight bearing did not negatively influence healing(5). Furthermore, a long term prospective study of 27 patients over 18 years found no association with weight-bearing in a TCC during acute CN management(6). As such weight bearing in a TCC appears to be safe.

Duration of Treatment

- Duration of immobilisation in acute CN varies widely in the literature from 2 to 12 months with an average of 6 months. Cessation of treatment has been based on either clinical or radiological resolution or a combination of the two. Clinical resolution is described as regression of swelling and erythema with stabilisation of temperature difference between two feet of less than 2 degrees centigrade. Radiological resolution is based on MRI imaging(7,8).
- A review by Felix et al. found no evidence to support one method versus the other, however the majority of published evidence supports clinical assessment over MRI(9). Radiological features of acute CN take longer to resolve than clinical features resulting in a longer duration of immobilisation.
- Completion of treatment is strongly associated with resolution of acute CN. In a retrospective series by Griffiths and Kaminski 48.1% of patients returned to normal footwear following completion of non-operative management with no observed charcot recurrences(10). A minority of 22.2% of patients required soft tissue or bone reconstructive surgery at a later date.

The Role of Pharmaceutical Therapy

- Pharmaceutical therapy has been robustly evaluated in the literature with level 1 evidence demonstrating no clinical benefit to the use of bisphosphonates, steroids or immunomodulators in the treatment of acute CN(11). A metanalysis of 5 randomised controlled trials found that median time to remission was actually prolonged with the use of pharmacotherapy versus immobilisation alone (18.5 versus 16.8 weeks) and is therefore not recommended.

Contralateral Foot Surveillance

- For those patients with charcot neuroarthropathy contralateral foot problems are common. Waibel et al. reported a 20% incidence of developing CN in the contralateral foot following treatment and 46% incidence of contralateral foot ulceration(12). It is therefore recommended that both feet are routinely checked during and after treatment for early recognition of evolving problems.

Chronic Phase

- In the latter remodelling phase of CN, Eichenholtz Stage 3, deformity can be managed non-operatively in selected cases. In instances where the deformity is stable and there is no concern for infection, soft tissue compromise or ulceration, surgery can be avoided. Custom shoes are critically important in preventing ulceration and have been shown to reduce midfoot plantar pressures by up to 80%.

Nice Guidelines for Acute CN

- NICE advises immobilisation in instances of suspected acute CN with an irremovable device in the first instances however recognises that there may be cases where this is impractical in which case a removable device can be offered. The use of bisphosphonates is not recommended other than in the context of a clinical trial. It is recommended that patients are monitored closely for signs of resolution through clinical assessment, primarily assessing temperature difference, and that radiographs can be used as an adjunct.

Summary

- Immobilisation with an irremovable cast is the treatment of choice for acute CN.
- Treatment must be initiated as soon as possible where acute CN is suspected.
- Treatment must be continued until features of acute CN resolve.
- Patients should be allowed to bear weight in a total contact cast.
- There is no role for pharmaceutical agents in the management of acute CN.

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5.4. The Role of Acute (Hot) Fixation In Charcot *Akshdeep Bawa*

What is Acute Charcot?

The classical definition rests on a temperature difference greater than two degrees between the two feet, the classical triad of raised temperature, oedema and erythema without a preceding wound, and disorganised bone and soft tissues.[1,2,3]

When that definition is examined against the evidence, however, it becomes less secure than it looks. The International Working Group on the Diabetic Foot conducted a systematic review of for its 2023 guideline on active Charcot neuro-osteoarthropathy.[4] What it found was that unilateral asymmetric temperature elevation is sensitive but not specific in diagnosing active disease, and, more fundamentally, that there is no gold-standard test to diagnose active Charcot. A combination of clinical signs with evidence of bone or joint injury on imaging, should be present to make a diagnosis of acute Charcot. The same problem afflicts the other end of the disease course: there is no standardised definition of remission and no agreed "gold-standard" test to establish it.[4]

What do the Guidelines Say?

The IWGDF guideline does address surgery in the active phase. Its recommendation is that:

"In a person with active Charcot neuro-osteoarthropathy and intact skin, and with instability of foot and ankle joints, and/or deformity with a high-risk of developing ulcer in the offloading device, or pain that cannot be sufficiently stabilised in a Total Contact Cast or a non-removable knee-high device, we suggest that surgical intervention should be considered (Conditional;Low)".

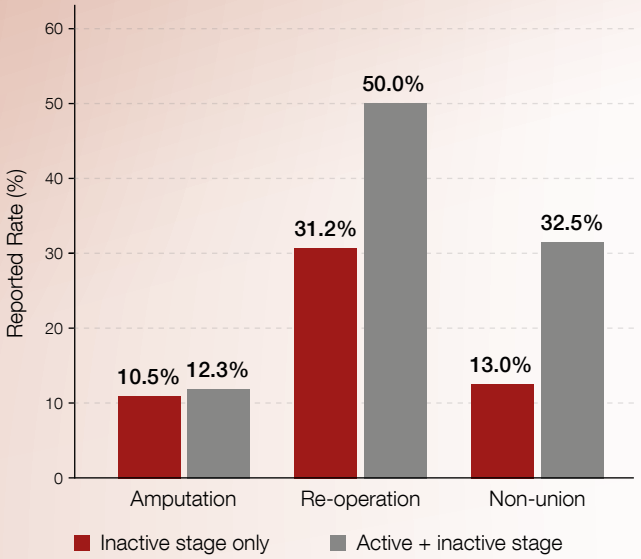
The strength of that recommendation is conditional and the quality of evidence is low.[4]

Should We Operate Before the Foot has Destroyed Itself?

The arguments against operating early are readily stated: poor bone quality, hostile soft tissues, and the fact that not all these feet are going to progress to full collapse.

A systematic review of surgical timing found increased re-operation rates, increased amputation rates and more non-unions when surgery was performed in a cohort where the surgery was done in active and inactive stages compared to a cohort where surgery was exclusively done in the non-active stage (Figure 6).[5]

Outcome by Stage at which Reconstruction was Performed



Data: Tan & Chua, systematic review of 17 studies. No study reported surgery in the active stage alone.

Figure 4. Outcomes by the stage at which reconstruction was performed.

The Perils of Surgery in the Active Phase

In a study of complications from ankle arthrodesis in diabetes-related Charcot foot syndrome, comparing diabetic patients with Charcot against diabetic patients without it, the Charcot group had substantially worse outcomes across the board: amputation at one year in 6.6 per cent against 1.9 per cent (odds ratio 3.66), overall amputation in 15.2 per cent against 5.0 per cent (odds ratio 3.43), hardware removal at one year in 22.7 per cent against 15.2 per cent (odds ratio 1.63), surgical site infection at 90 days in 16.4 per cent against 7.4 per cent (odds ratio 2.46) and at 30 days in 8.8 per cent against 3.6 per cent (odds ratio 2.60), all with $P<0.0001$.[6] That is roughly three times the amputation rate in a comparably comorbid population.

Arguments for a paradigm shift towards earlier intervention have been made,[7] and arthrodesis has been proposed as an early alternative to non-operative management of Charcot arthropathy of the diabetic foot.[8]

Fixation Strategies

The choice of fixation depends on the pattern of collapse, the quality of the soft tissues, and the surgeon's experience. Intramedullary beaming remains the workhorse for the midfoot; tibiotalocalcaneal fixation is reserved for the catastrophic cases involving the hindfoot. The superconstruct concept, in which internal fixation is extended beyond the zone of injury with stronger, load-sharing implants, was itself described in the context of inactive rather than active disease.[9]

Beaming alone has been examined critically. A group from Germany reported that intramedullary medial column support with the midfoot fusion bolt is not sufficient for bony union of arthrodesis in neuro-osteoarthropathic feet: the intramedullary rod does not provide adequate stability to achieve bony union, and implant loosening and deep infections were detected in most of their cases. Their conclusion was that to augment the fixation by additional implants such as angular stable plates over the medial column, together with additional stabilisation of the lateral column.[10]

What About Frames?

External fixation might be expected to circumvent the soft-tissue problem, but the evidence is poor. In studies where external fixation was the method of stabilisation, mean time to weight bearing was 19 weeks, longer than the 16 weeks observed with internal fixation, and it is clinically unclear how much benefit the three weeks would confer.11 In the series describing management of acute Charcot fracture-dislocations with the Taylor spatial external fixation system, the authors' own protocol was that after osseous consolidation the frame is removed, most commonly under local anaesthesia, and consolidation is assessed under image intensification; if motion is detected, multiple large cannulated screws are inserted in multiple planes to provide internal splintage - described as rebar - in order to allow continued osseous apposition and to limit delayed collapse of the corrected deformity.[12]

Outcomes

The systematic review of Charcot foot reconstruction outcomes is the most useful summary available. Its conclusion was that although there was no preference of one method of fixation over another, currently the fixation options and techniques provide high rates of limb salvage and low risk of amputation. However, the evidence quality is low due to the scarcity of controlled studies, inconsistency in reporting outcomes and heterogeneity of study groups.[11]

The complication figures from the same review were high at 36 per cent overall. Complications in patients treated with external fixators were lower at 26 per cent, compared with 43 per cent for internal fixation, although pin-site infections were under-reported, which may explain this the discrepancy. Where internal and external fixation were combined in the same patient, the complication rate was higher at 64 per cent, although the numbers were too small to support definitive conclusions. The rate of recurrent ulceration or failure of healing of an ulcer was 6.25 per cent, and the post-reconstruction amputation rate was low at 5.5 percent.[11]

The limitation the authors acknowledged is important: the median number of patients per study in the review was 24, or 26.7 feet, which is small, and most of the larger series come from selected specialist centres, which in itself can be considered a bias.[11]

When to Intervene

The most practical guidance offered came from Tiruveedhula et al[13] where they proposed a new classification system for Charcot. They divided acute midfoot Charcot presentations into stable and unstable. The proposition is that if the foot remains unstable at six weeks, with a dropped cuboid height, midfoot reconstruction should be planned; a cuboid lying below the weight-bearing axis is a precursor to ulceration.[13]

Where a deep ulcer (with underlying osteomyelitis) is already present on presentation of active Charcot, the approach used and agreed by most of the large UK diabetic foot centres, is a two-stage surgical reconstruction.

How Long Do Patients Wait?

Ahmed et al[14] study on time-critical Charcot foot reconstructions concluded that these can be safely performed in the absence of optimal pre-operative glycaemic control when delivered by a multidisciplinary team.[14] A detail from that paper deserves attention. The mean duration of waiting time to surgery, defined as the interval between listing and the operation being performed, was 11 months, with a minimum of 6 and a maximum of 14 months.[14] The description “time-critical” therefore needs reading against a mean wait of nearly a year.

The 'Flipper Foot'

A recent alternative approach argues for addressing the midfoot deformity indirectly by tibiotalocalcaneal arthrodesis while preserving motion at the level of the midfoot. The reasoning is that intramedullary beaming for midfoot Charcot reconstruction spans the zone of collapse but does not address the principal deforming force, which is the plantarflexed equinus talus that drives midfoot apex pressure and rocker-bottom ulceration. The proposed alternative is rigid hindfoot tibiotalocalcaneal arthrodesis that repositions the talus, restoring heel-first initial floor contact and unloading the midfoot, combined with debridement and resection of the collapsed midfoot rather than midfoot fixation.[15]

Twelve consecutive patients with midfoot Charcot who underwent tibiotalocalcaneal fusion via a retrograde hindfoot nail were retrospectively reviewed. Mean age was 61.33 years. 11 patients were diabetic (9 TIIDM, 2 TIDM) while 1 patient had idiopathic neuropathy. 3 patients had a residual ulcer at the time of the surgery. Fusion was achieved in 10/12 patients at an average of 14.2 weeks. Non unions were asymptomatic, and all patients had a functional plantigrade foot post-operatively. None of the patients had developed recurrent ulcerations at the 1-year mark. No hardware failure or proximal amputations were observed.[15]

Treat the Disease, Not the Consequence

Pursuing better fixation techniques and protocols in the field of Charcot Neuroarthropathy may be “barking up the wrong tree”. If fixation is the answer to the deformity, it is not the answer to the disease. Three research priorities were proposed:

1. Early reversal of pathophysiology - treat the disease, not just the consequence

2. Research into optimisation/shortening duration of the acute phase

3. High plasma RANKL and OPG levels at diagnosis of Charcot

The role of Wnt/β-catenin and RANKL/OPG signalling in bone healing has been examined prospectively in 24 diabetic Charcot patients followed for two years.[16] And the effect of a single dose of RANKL antibody treatment on acute Charcot neuro-osteoarthropathy of the foot has been studied directly.[17] This raises the question on whether future research in the field of Charcot neuroarthropathy should be directed to devise strategies to address the pathophysiology rather than the end result.

Summary

- There is no gold-standard test for active Charcot and no standardised definition of remission. Asymmetric temperature elevation is sensitive but not specific; diagnosis needs clinical signs together with imaging evidence of bone or joint injury.
- The IWGDF does support surgery in the active phase, but only conditionally and on low-quality evidence: instability, deformity at high risk of ulcerating in the offloading device, or pain that cannot be controlled in a total contact cast.
- The timing data argue for caution. Cohorts that include active-stage surgery show higher amputation, re-operation and non-union rates than those confined to the inactive stage.
- Charcot patients undergoing ankle arthrodesis fare substantially worse than comparably comorbid diabetic patients without Charcot.
- The unresolved point is that fixation treats the consequence. Reversing the pathophysiology early, shortening the active phase and exploring RANKL/OPG-directed therapy are proposed questions for future research.

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Consensus Questions

1. Acute Charcot neuroarthropathy should always be suspected in a diabetic patient with a swollen, warm midfoot.
   a. Yes 17 (89.5%)
   b. Abstain 2 (10.5%)
2. Offloading should be the first intervention for suspected acute Charcot neuroarthropathy.
   a. Yes 17 (89.5%)
   b. Abstain 2 (10.5%)
3. An irremovable cast rather than a removable device is preferred for the offloading period in acute Charcot neuroarthropathy.
   a. Yes 17 (89.5%)
   b. Abstain 2 (10.5%)
4. A removable device is acceptable in certain circumstances for offloading in acute Charcot neuroarthropathy.
   a. Yes 17 (89.5%)
   b. Abstain 2 (10.5%)
5. For the vast majority of patients with midfoot Charcot the treatment is non-operative.
   a. Yes 17 (89.5%)
   b. Abstain 2 (10.5%)
6. Achilles or gastrocnemius lengthening should be considered in all patients with Charcot neuroarthropathy.
   a. Yes 17 (89.5%)
   b. Abstain 2 (10.5%)

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