Forefoot

Anish R. Kadakia, Paul J. Switaj, Bryant S. Ho, Mohammed Alshouli, Daniel Fuchs, and George Ochengele

1 Hallux Rigidus

Take-Home Message

- Pain and stiffness of the first metatarsophalangeal (MTP) joint consistent with degenerative disease of the first MTP.
- Nonsurgical management should be attempted first, with the goal of avoiding painful first MTP joint dorsiflexion – Morton's extension carbon fiber plate.
- Surgery is determined based on radiographic and physical exam findings. Cheilectomy – >50 % joint preservation or negative grind test. Arthrodesis – <50 % joint preservation with a positive grind test or total joint obliteration or deformity (associated hallux valgus or varus).

Definition

- Functional limitation of motion of the first metatarsophalangeal joint in adults due to degenerative arthritis often associated with dorsal osteophyte

A.R. Kadakia (✉) • P.J. Switaj • B.S. Ho • M. Alshouli
D. Fuchs • G. Ochengele
Department of Orthopedic Surgery,
Northwestern University – Feinberg School of Medicine,
Northwestern Memorial Hospital, Chicago, IL, USA
e-mail: Kadak259@gmail.com; paul.switaj@gmail.com;
bryant.s.ho@gmail.com; mtshouli@gmail.com; dfuchs0011@gmail.com;
gochenjele@gmail.com

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Etiology

- Idiopathic arthritis
- *Extrinsic causes*
  - Post-traumatic arthritis: intra-articular fractures, repetitive dorsiflexion-compression injuries, and hyperdorsiflexion injury
  - Improper shoe wear: high-heeled shoes, pointed-toe shoes, and shoes with small or short toe boxes
- *Intrinsic causes*
  - Secondary to inflammatory arthropathies

Pathophysiology

- Change in the first MTP joint biomechanics leads to displacement of the instant centers of motion to an eccentric position on the first metatarsal head and higher plantar pressures.
- Contracted flexor hallucis longus (FHL) may increase plantar pressures and MTP joint force.
- Clinical presentation
  - Pain with shoe wear secondary to pressure over dorsal osteophyte
  - Limited range of motion (limited ability to wear heels)
  - Pain with activity

Radiography

- Weight-bearing anteroposterior, lateral, and oblique views → Look for narrowing of the joint space, osteophytes at the lateral and dorsal surface of the joint, flattened first metatarsal head, and subchondral cysts (Fig. 1).
- MRI scan: look for osteochondral injury in the setting of normal X-rays.

Classification Coughlin clinical-radiographic classification of hallux rigidus (Table 1)

Treatment Algorithm *Nonoperative*: short period of rest followed by activity modifications, NSAIDS, intra-articular steroid injections, shoe modification (rigid sole). Orthotic = Morton's extension carbon fiber plate
Operative (Table 2)

- Simplified
  - Cheilectomy: some preservation of joint space without pain in the central range of motion (Grades 1–3) (Fig. 2)
  - Fusion for deformity, pain with grind at central range of motion (grade 4), 100 % joint space loss, no motion (Figs. 3 and 4)

Complications

- Persistent pain
- Recurrence of osteophyte formation

Fig. 1 AP and lateral view of a patient with hallux rigidus. Note the narrowing of the joint space on the AP with the common findings of a dorsal osteophyte on the metatarsal head with a loose body within the first MTP. Hallux rigidus is most easily identified on the lateral radiograph

- Progression of joint degeneration requiring additional surgery
- Iatrogenic hallux valgus or varus deformity
- Nonunion or malunion (ideal position – neutral rotation, slight hallux valgus, and dorsiflexion parallel to the floor. Best done with a flat plate intraoperatively to simulate the final clinical position. Superior to absolute values secondary to anatomic variability)

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Table 1 Coughlin clinical-radiographic classification of hallux rigidus

Grade	Dorsiflexion	Radiographic findings	Clinical findings
0	40–60° and/or 10–20 % loss compared with normal side	Normal	No pain; stiffness, loss of motion
1	30–40° and/or 20–50 % loss compared with normal side	Dorsal osteophytes; minimal joint-space narrowing, periarticular sclerosis, flattening of metatarsal head	Pain at extremes of dorsiflexion and/or plantar flexion
2	10–30° and/or 50–75 % loss compared with normal side	Dorsal, lateral, and possibly medial osteophytes; flattened appearance to metatarsal head, ¼ or less of dorsal joint space involved on lateral radiograph, mild-to-moderate joint-space narrowing and sclerosis; sesamoids not usually involved	Moderate-to-severe pain and stiffness; pain occurs just before maximum dorsiflexion/plantar flexion on examination
3	=10° and/or 75–100 % loss compared with normal side. There is notable loss of metatarsophalangeal plantar flexion	Substantial joint space narrowing, periarticular cystic changes, more than 1/4 of dorsal joint space involved on lateral radiograph, sesamoids enlarged and/or cystic and/or irregular	Constant pain and stiffness at extremes of range of motion but not at mid-range
4	Same as in Grade 3	Same as in Grade 3	Definite pain at mid-range of passive motion

Table 2 Operative algorithm for hallux rigidus

Grade	Operative
0	Arthroscopic or open débridement, drilling, or grafting of metatarsal head OCD (if present)
1	Cheilectomy
2	Cheilectomy
3	Cheilectomy
4	MTP joint arthrodesis

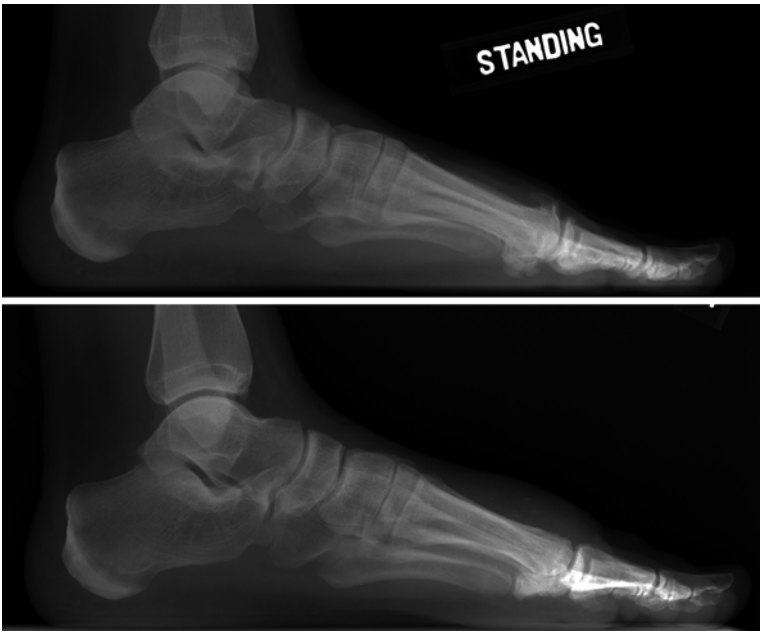

Fig. 2 Preoperative appearance of the dorsal osteophyte (*top radiograph*) and the postoperative appearance (*bottom radiograph*) following a cheilectomy. No more than 30 % of the metatarsal head should be resected to prevent iatrogenic instability

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2 Hallux Valgus

Take-Home Message

- Hallux valgus is defined as a lateral deviation of the great toe with medial deviation of the first metatarsal.
- DJD of the first MTP requires arthrodesis.
- Hypermobility of first TMT requires Lapidus (first TMT arthrodesis).
- Increased DMAA required redirectional osteotomy of distal metatarsal, in addition to other required osteotomies to correct the IMA.
- Increased HVI requires an Akin osteotomy (medial closing wedge of phalanx).

Fig. 3 Patient presented with hallux valgus and hallux rigidus (**a**). Correction of both deformities is best corrected with an arthrodesis (**b**) as an isolated cheilectomy or osteotomy to correct the hallux valgus will not be successful

Definition Hallux valgus is defined as a lateral deviation of the great toe with medial deviation of the first metatarsal (Fig. 5).

Etiology Related to multiple factors and more common in females

Extrinsic Causes

Improper shoe wear (high-heeled shoes, pointed-toe shoes, and shoes with narrow toe boxes)

Intrinsic Causes

- Genetic predisposition, ligamentous laxity, and predisposing anatomy (convex metatarsal head, pes planus) are contributory.
- Inflammatory arthropathies (rheumatoid arthritis), metabolic bone disorders (gout), neuromuscular disorders (cerebral palsy, stroke)

Fig. 4 Patient with grade 4 hallux rigidus (**a**) (>50 % joint space loss with central grind). This is best treated with an arthrodesis (**b**)

Pathoanatomy

- Medial capsular attenuation.
- Proximal phalanx drifts laterally, leading to the following conditions:
  - Plantar-lateral migration of abductor hallucis; change in position causes the muscle to plantar flex and pronate the phalanx.
  - Stretching of the extensor hood of the extensor hallucis longus.
  - Lateral deviation of the extensor hallucis longus and flexor hallucis longus (FHL), causing a muscular imbalance and deforming force for valgus progression and pronation of the great toe.
- The first metatarsal head moves medially off the sesamoids, increasing the intermetatarsal angle (IMA).

Fig. 5 Two patients (**a**, **b**) with hallux valgus deformity. Note the increased medial deviation of the metatarsal head in the patient with a more severe deformity (**b**)

- Secondary contracture of the lateral capsule, adductor hallucis, lateral metatarsal-sesamoid ligament, and intermetatarsal ligament.

Radiography

- Multiple measurements can be obtained from standard radiographs that guide treatment options
  - Hallux valgus angle (HVA): angle formed by a line along the first metatarsal shaft and a line along the shaft of proximal phalanx (Fig. 6)
    - Normal <15°
  - First to second intermetatarsal angle (IMA): angle formed by a line along the first metatarsal shaft and a line along the second metatarsal shaft (Fig. 7)
    - Normal <9°
  - Hallux valgus interphalangeus (HVI) angle: angle formed by a line along the shaft of proximal phalanx and a line along the shaft of distal phalanx (Fig. 8)

Fig. 6 AP radiograph denoting the hallux valgus angle. The acute angle (*HV*) formed by a line parallel to the first metatarsal shaft and a line parallel to the proximal phalangeal shaft is measured

- Normal <10°
- Associated with a congruent deformity

– Distal metatarsal articular angle (DMAA): angle formed by a line along the articular surface of the first metatarsal and a line perpendicular to the axis of the first metatarsal

- Normal <10°
- Associated with a congruent deformity

Classification

- There is no specific classification for hallux valgus that is routinely utilized. Specific recommendations are based upon the degree of deformity, which is discussed below.

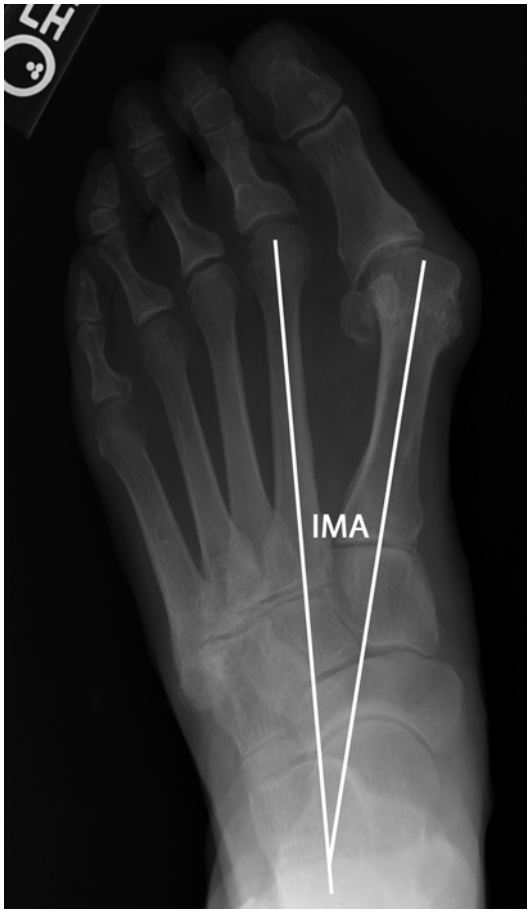

Fig. 7 AP radiograph denoting the intermetatarsal angle. The acute angle (*IMA*) formed by a line parallel to the first metatarsal shaft and the second metatarsal shaft is measured

- The use of the term congruency has been utilized and is a source of confusion
  - Congruency is determined by comparing the line connecting the medial and lateral edge of the first metatarsal head articular surface with the similar line for the proximal phalanx, and when these lines are parallel, the joint is congruent; otherwise, it is incongruent (Fig. 9).
  - The implication is that the patient has an intrinsic deformity of either an increased DMAA or HVI. These can be present with an incongruent deformity as well, and therefore each radiograph must be carefully reviewed.

Fig. 8 AP radiograph of the proximal phalanx denoting the hallux valgus interphalangeus angle. A *line* is drawn parallel to the proximal and distal articular surfaces. Perpendicular lines are drawn relative to these lines. The acute angle (*HVI*) formed by the perpendiculars is measured

Treatment

Nonoperative

NSAIDS for associated bursitis, shoe modifications (wide toe box, flat sole), orthotics (arch support in flat foot and metatarsal pad for second metatarsalgia), toe spacers if flexible deformity. These will not correct the deformity.

Operative

Algorithmic approach to identifying the appropriate surgical intervention. Rigid deformity, pain within the first MTP joint, inflammatory arthropathy, or radiographic evidence of arthritis requires the first MTP arthrodesis (Fig. 10).

All patients should undergo a soft tissue release with all associated osteotomies and the first TMT arthrodesis (Lapidus).

Fig. 9 This patient has an incongruent deformity noted by the lack of parallelism between the articular surface of the metatarsal and the proximal phalanx

IMA is ≤13° and HVA is ≤40°

- Distal metatarsal osteotomy (chevron) (Fig. 11)
- Distal soft tissue release
- Medial eminence resection and capsular repair

IMA is >13° or HVA is >40°

- Proximal metatarsal osteotomy
- Distal soft tissue release
- Medial eminence resection and capsular repair

Instability of the First TMT/Joint Laxity

- Lapidus (fusion of the first TMT joint) (Fig. 12)
- Soft tissue release
- Medial eminence resection and capsular repair

Fig. 10 This patient has a significant hallux valgus deformity with hallux rigidus and pain within the first MTP joint. (**a**) Correction of both the IMA and HVA is easily achieved with an arthrodesis without the need for additional metatarsal osteotomy (**b**)

Increased DMAA (>10°)

- Distal medial closed-wedge metatarsal osteotomy in addition to what is required based on the angular measurements.
  - IMA is ≤13°, and HVA is ≤40°
    - Distal biplanar closed-wedge metatarsal osteotomy.
    - Translate and redirect the metatarsal head simultaneously.
  - IMA is >13° HVA is >40°
    - Proximal metatarsal osteotomy and distal medial closed-wedge metatarsal osteotomy (Fig. 13)
  - Instability of the first TMT/joint laxity
    - Lapidus and distal medial closed-wedge metatarsal osteotomy

Fig. 11 In patients with a HVA ≤40 and an IMA ≤13 (**a**), a distal osteotomy with soft tissue correction is the most appropriate procedure (**b**)

Hallux valgus interphalangeus

- Akin osteotomy can be done in isolation if no other deformity present.
- Commonly performed in addition to other procedures.

Complications

- Avascular necrosis (AVN)
  - Distal metatarsal osteotomy and lateral soft tissue release may be performed simultaneously without increased risk of AVN.
- Recurrence
  - Can occur with any procedure – highly associated with:
    - Under correction of the IMA
    - Isolated soft tissue reconstruction (modified McBride)
    - Isolated resection of the medial eminence
- Dorsal malunion
  - Results in transfer metatarsalgia – highly associated with:

Fig. 12 Regardless of preoperative deformity (**a**), in a patient with hypermobility, a Lapidus procedure is required (**b**)

  - Lapidus (first TMT fusion)
  - Proximal crescentic osteotomy

- Hallux Varus (Fig. 14)

– Resection of the fibular sesamoid (original McBride)
– Over-resection of the medial eminence
– Excessive lateral release
– Overcorrection of the IMA

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Fig. 13 In this patient with an IMA >13 and an increased DMAA >10 (**a**), a double osteotomy is required (**b**). A proximal osteotomy in addition to a distal closing wedge osteotomy fully corrects the deformity

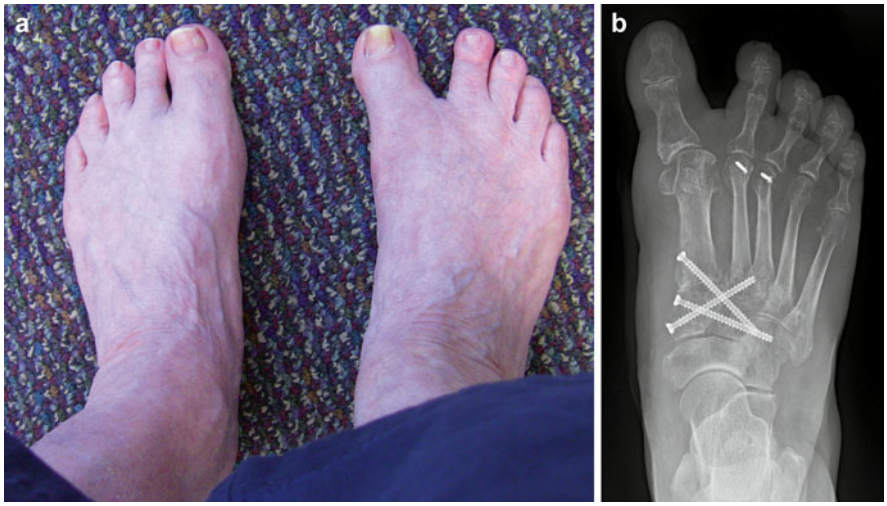

Fig. 14 In this patient with clinical hallux varus (**a**), the etiology is the overcorrection of the IM angle with excessive lateral release (**b**)

3 Interdigital Neuroma

Take-Home Message

- Classically, a patient with a symptomatic interdigital neuroma complains of pain located on the plantar aspect of the foot at or distal to the metatarsal heads. The pain is described as burning, often with radiation to the toes.
- Adjacent or multiple neuroma is an uncommon diagnosis and should alert the surgeon to the possibility of alternate diagnoses.
- Excision of neuroma from either a dorsal (higher rate of missed neuroma) or plantar (higher rate of painful scar) approach is the surgical treatment of choice.

Definition

- A neuralgia of the interdigital nerve in the forefoot due to entrapment of the nerve near the distal edge of the transverse intermetatarsal ligament

Etiology

Extrinsic Causes

- Mass effect from soft tissues
- Extrinsic mechanical stresses → improper shoe wear (high-heeled shoes, pointed-toe shoes, and shoes with small or short toe boxes) – result in compression and tensile stress on the nerve (from dorsiflexion)

Intrinsic Causes

- Ischemic changes to the perineural tissue
- Repetitive microtrauma affecting the nerve
- Traditionally, it was thought that both the medial and lateral plantar nerves send branches to the third web space, creating a larger nerve that was predisposed to increased microtrauma. However, the incidence of a communicating branch to the third web space was noted at 27 %, decreasing support of the anatomic theory.

Pathophysiology

- Histologic analysis has revealed that the nerve is affected distal to the intermetatarsal ligament.
- Fusiform swelling of the nerve has generated the term *neuroma*.
- Chronic entrapment leads to sclerosis and edema of the endoneurium, thickening of the perineurium, deposition of eosinophilic material, and demyelination of nerve fibers distal to the ligament.
- The culmination of this pathologic process is an increased diameter of the affected nerve through intrasubstance hypertrophy and swelling.

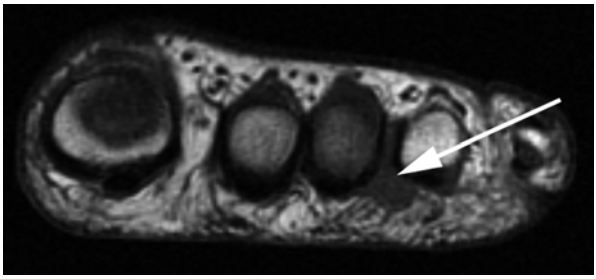

Fig. 15 Coronal T1 image of a Morton's neuroma (*arrow*). Note that the neuroma is pear shaped and is plantar to the intermetatarsal ligament

Radiography

- Three views of weight bearing of the foot should be performed to rule out any pathologic process of the metatarsophalangeal joint.
- Ultrasonography has demonstrated a high sensitivity with a variable specificity in the diagnosis of a neuroma and, however, is not required to make the diagnosis.
- Currently, an MRI scan may detect aberrant pathology such as a cyst or ganglion; however, it may show thickening of the nerve (Fig. 15). The routine use of MRI to identify a neuroma is not indicated given the difficulty of interpreting the clinical value of the findings.
- In general, the diagnosis is usually made without the use of ultrasound or MRI and should only be considered with rare clinical presentations.

Diagnostic Tests

- Lidocaine injection test: lidocaine is injected approximately 2 cm proximal to the metatarsal head, below the intermetatarsal ligament → resolution of symptoms confirms the diagnosis.
- Mulder's test: squeeze the transverse arch of the foot and apply pressure between the interdigital space; a positive test will result in a click, as well as pain in the plantar surface of the involved interspace with paresthesias radiating into the affected toes.

Treatment

Nonoperative: shoe modification (soft shoe with wide toe box and firm sole that provides metatarsal support), modification of daily activity, NSAIDS, corticosteroid injection
Operative: indicated after failure of nonoperative treatment

- Excision of the neuroma can be carried out through the dorsal or plantar approach to the web space. Isolated intermetatarsal ligament release is not appropriate.
  - Dorsal approach requires sectioning of the transverse metatarsal ligament (Fig. 16). However, this approach may result in failure to excise the neuroma in 5 % of cases (Fig. 17).
  - Plantar approach spares the intermetatarsal ligament and is noted to universally achieve nerve resection, however, results in a painful plantar scar in 5 % of patients.
- Successful in 75–90 % of cases

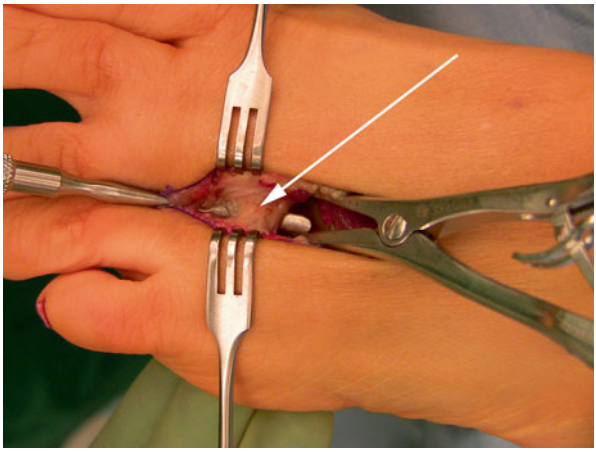

Fig. 16 The intermetatarsal ligament (*arrow*) must be incised with the use of a dorsal approach in order to visualize the neuroma

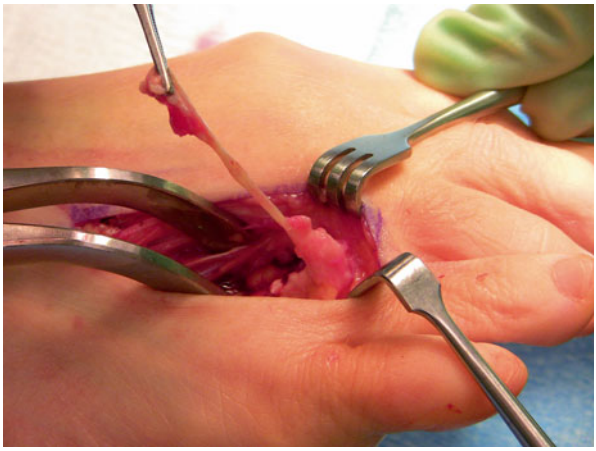

Fig. 17 The digital nerve has been transected proximally and elevated out of the wound. Adequate proximal resection must be performed in order to prevent recurrence. Surgical pathology confirmed the diagnosis of neuroma

Complications

- Painful plantar scars or plantar keratosis with surgical plantar approach
- Regeneration or formation of stump neuroma
- Residual tenderness and/or numbness
- Infection, plantar fat atrophy (related to steroid injections)
- Digital ischemia if adjacent vascular structures injured

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4 Lesser Toe Deformities

Take-Home Message
- Lesser toe deformities can present with pain, contractures, and callosities formation at the plantar MTP (claw toes), dorsal PIP (hammer and claw toes), or tip of the distal phalanx (mallet, hammer, or claw toes).
- Vertical Lachman's test (drawer test) for the lesser MTP joints that results in pain is highly sensitive for plantar plate rupture.
- Clinical assessment of degree of flexibility (flexible or fixed) is the key role in treatment.

Definition

- *Claw toe*: flexion deformities of the distal interphalangeal (DIP) joint and the proximal interphalangeal (PIP) joint with fixed hyperextension at the metatarsophalangeal (MTP) joint (Fig. 18).
- *Mallet toe*: flexion deformity at the DIP joint with the PIP and MTP joints in neutral position.
- *Hammer toe*: flexion of the PIP joint with flexion or extension of the DIP. With weight bearing, the MTP joint will appear extended; however, this should correct with as the foot is elevated from the ground. The MTP extension is secondary to the flexion deformity of the PIP joint (Fig. 19).
- *Crossover toe:* Defined by rupture of the plantar plate with associated attenuation of the lateral collateral ligament. This results in multiplanar instability of the toe with the end-stage deformity of the second toe (most common) overlapping the great toe (Fig. 20).

Etiology and Pathophysiology

- Lesser toe deformities occur much more commonly in women (up to 5:1 ratio), thought to be secondary to high fashion shoe wear which constricts the forefoot and maintains the MTP joints in hyperextension.
  - A hammer deformity most commonly involves the second toe due to its relative length compared to the remainder of the lesser toes. A short toe box will cause the second toe to buckle and extend at the MTP joint.

Fig. 18 Dorsal and plantar view of a patient with severe claw toes affecting primarily the second and third toes. Note the severe callus (*arrowhead*) on the plantar aspect of the second and third metatarsal heads

Fig. 19 Hammertoe deformity of the toes two through five in a patient. As opposed to claw toes, the MTP extension resolves with removing the foot off the floor

Fig. 20 Crossover toe deformity of multiple toes in a patient who has long-standing hallux valgus deformity. Note how the toe has deformity in multiple planes. Not only is it extended in the sagittal plane, the toe is deviated in the coronal plane as well

- Chronic positioning of the MTP joint in hyperextension will attenuate the static plantar structures, which underlies both claw toes and crossover toe deformities.
- Cavus deformity, neuromuscular diseases that affect the balance of the extrinsic and intrinsic musculature inflammatory arthropathies that lead to attenuation of soft tissue structures and instability of the MTP joint, and trauma have all been implicated in the etiology of claw toes.
- Claw toes are a noted complication of compartment syndrome involving the deep compartments of the foot.

Radiography Three views of the foot weight bearing should be performed to identify if dislocations of the metatarsophalangeal joints have occurred as this will alter surgical management. Additionally, in chronic cases, the presence of arthrosis should be noted as this will alter surgical management as well.

Classification The lesser toe deformities are classified as detailed above, but critically differentiated if they are flexible (reducible) or fixed (irreducible).

Treatment

Nonoperative

- Adequate padding, shoe wear modifications with an adequate shoe box to provide sufficient space for the toes and silicone toe caps to protect the toes are useful.

- Orthotic management may be accomplished by simple (i.e., metatarsal pads) or custom orthotics to include a metatarsal bar and well-outs for the affected metatarsal heads.

Operative

Persistent pain despite shoe wear modification or significant pressure sores, creating an at-risk environment for an ulcer, or history of ulceration secondary to shoe wear

- General principles: flexible ->soft tissue reconstruction. Fixed ->bone procedures required
- Mallet Toe
  - Flexible – flexor tenotomy at DIP
  - Fixed – DIP arthroplasty/fusion
- Hammer Toe
  - Flexible – flexor tenotomy at PIP or flexor to extensor tendon transfer (if mild MTP extension noted)
  - Fixed – PIP arthroplasty or arthrodesis (Fig. 21)
- Claw Toe
  - Flexible – flexor to extensor tendon transfer
  - Fixed – PIP arthroplasty or arthrodesis with associated MTP capsulotomy and extensor lengthening
    - Dislocated or unstable MTP joint
      - Requires shortening osteotomy of the metatarsal
- Crossover Toe
  - Flexible
    - Direct repair of the plantar plate has demonstrated clinical success and directly corrects the pathology.
    - Alternate options include flexor to extensor tendon transfer or transfer of the EHB deep to the intermetatarsal ligament.
  - Fixed
    - Metatarsal shortening osteotomy to reduce the MTP with associated soft tissue correction detailed above

Complications

- Recurrence of the deformity
- Floating toe (noted with a Weil osteotomy)
- Interdigital joint Instability
- Loss of active motion of the affected toe (occurs commonly secondary to the altered tendon function from tenotomies or bony shortening)

Fig. 21 PIP arthroplasty for a patient with a rigid hammer toe deformity of the fourth (**a**). Exposure of the distal aspect of the proximal phalanx (**b**) is followed by resection of the distal 3–4 mm of the phalanx (**c**) to allow the rigid deformity to correct (**d**). Pinning is performed to stabilize the toe for 4 weeks

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5 Freiberg's Disease

Take-Home Message
- Incompetence of the first ray (elevation or shortening) may be a causal factor and must be addressed when treating the second ray.
- Aggressive early conservative management may prevent late-stage arthritis by minimizing further extrinsic trauma to the metatarsal head.
- Surgical management: If no arthritis, then dorsal closing wedge osteotomy of the second metatarsal. If arthritis is present, then an MTP arthroplasty with interposition versus metatarsal head excision.

Definition Osteochondrosis of unknown origin that occurs in the metatarsal head, most commonly affects the second and, however, can also affect the third and fourth. Most commonly occurs in second decade of life and in women

Etiology *Primarily Unknown*

Extrinsic causes: repetitive microtrauma of the subchondral bone secondary to impact activity (running, sports, high-heeled shoes). Increased load transfer during gait secondary to an iatrogenically elevated, short, or unstable first metatarsal most commonly occurs following correction of hallux valgus.

Intrinsic causes: avascular necrosis, inflammatory arthropathies, predisposing anatomy (relatively long second metatarsal compared to the first), corticosteroids

Pathophysiology

A disruption in the blood supply due to mechanical or inflammatory process leading to eventual infarction and weakening of the bony architecture with concomitant disruption of articular surface. Persistent trauma leads to collapse of the weakened metatarsal head that progresses to arthrosis as the cartilage degenerates.

Pain within the affected MTP with swelling, thickening, and decreased range of motion.

Radiography Weight-bearing anteroposterior, lateral, and oblique views are required.

Common findings in Freiberg's disease include:

Resorption of the central metatarsal bone adjacent to the articular surface with flattening of the metatarsal head (Fig. 22)

Osteochondral loose bodies

Joint space narrowing in late-stage disease with associated osteophyte formation along with collapse of the articular surface (Fig. 23)

MRI scan: Low T1 and variable T2 fat sat in the subchondral bone of the metatarsal head with flattening

Fig. 22 Note the flattening of the metatarsal head that is commonly seen with Freiberg's disease (*arrow*). This patient had a prior silicone arthroplasty of the great toe and developed Freiberg's disease secondary to overload from an incompetent first ray

Fig. 23 Focused AP view of the forefoot demonstrating the natural history and long-term sequela of untreated Freiberg's. Note the significant subchondral cysts and osteophyte formation indicating OA

Fig. 24 Loose body removal in a patient who requires a dorsal closing wedge osteotomy

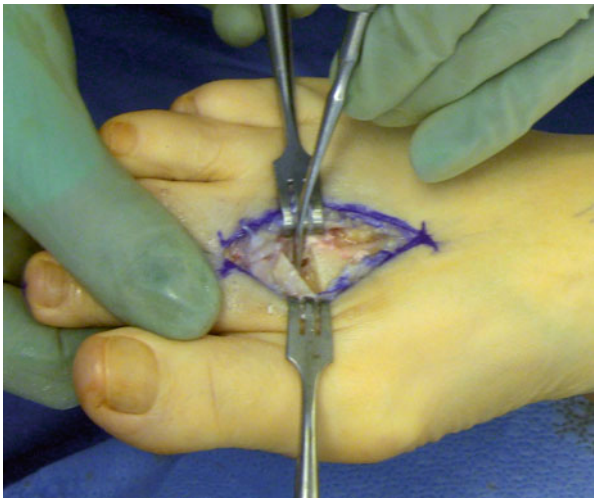

Fig. 25 A freer is placed in the osteotomy demonstrating the amount of bone that was resected. Note the dorsal to plantar direction of the osteotomy. The intact plantar cartilage will be rotated dorsally and recreate the dorsal articular surface

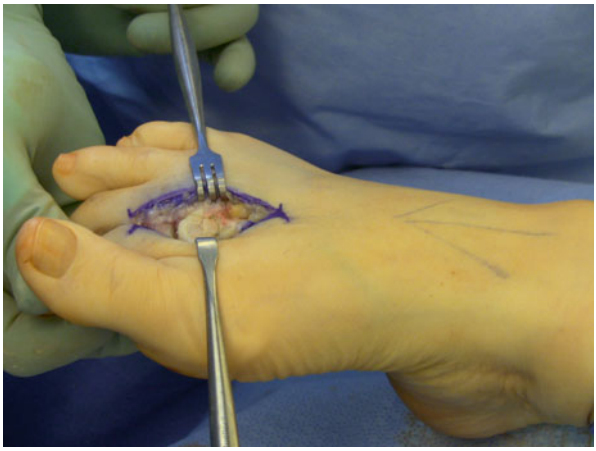

Fig. 26 Final appearance of the osteotomy after closure. Note the intact plantar cartilage now clearly present dorsally

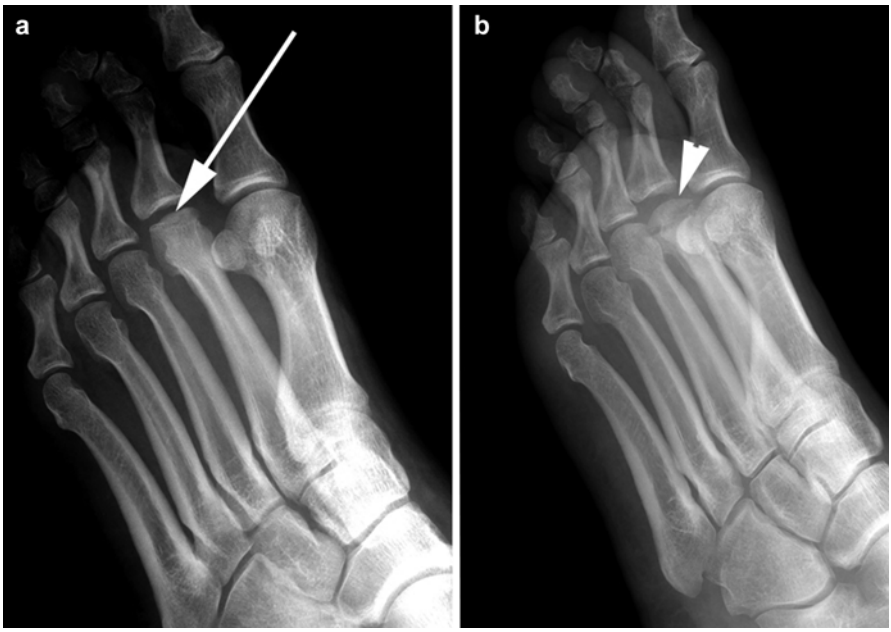

Fig. 27 Radiograph of a patient with Freiberg's disease (**a**) with the characteristic flattening of the metatarsal head (*arrow*) treated with a dorsal closing wedge osteotomy (**b**). Note how the contour of the metatarsal head has been recreated (*arrowhead*)

Classification

Smillie radiographic classification of the metatarsal head appearance	
Stage I	Fracture of the epiphysis
Stage II	Subsidence of the central portion (altered head contour)
Stage III	Central reabsorption
Stage IV	Loose body separation
Stage V	Flattening, deformity, arthritis of the metatarsal head

Treatment

	Nonoperative	Operative
Clinical indication	Early stage of disease/low demand in late stage	Failed conservative treatment and/or advanced stage of disease
Options	(a) Activity modifications (elimination of impact) (b) Protected weight bearing in a short CAM walker or short leg cast with toe extensions with crutches (c) NSAIDS (d) Shoe modifications (wide toe box, extra depth, flat rigid sole) (e) Full-length semirigid orthosis with metatarsal bar or pad	1. Early – synovitis: simple débridement and loose body removal (Fig. 24) 2. Late – joint collapse without arthritis: metatarsal dorsal closing wedge osteotomy with resection of nonviable bone and cartilage (Figs. 25, 26, and 27) 3. Late – arthritis: resection arthroplasty or interpositional arthroplasty. If severe and low demand, metatarsal head excision can be considered 4. *In all cases:* correction of the biomechanics of the foot must be performed (restore WB of the first metatarsal and/or shorten second metatarsal as indicated)

Complications

- Progression of joint degeneration
- Transfer metatarsalgia
- Limited ROM with extension contracture

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6 Sesamoids

Take-Home Message
- Turf toe is a complex injury to the sesamoid complex and plantar plate of the 1st MTP joint. Return to play requires 60° of painless dorsiflexion.
- The most effective treatment for pain secondary to the sesamoid is isolated sesamoid resection.
- Tibial > fibular

Definition The sesamoids are embedded within the tendons of flexor hallucis brevis. They are connected to each other by the intersesamoid ligament, and each sesamoid has an associated ligament inserting onto its respective side of the metatarsal head. The sesamoids function to increase the mechanical force of the flexor hallucis brevis (FHB) in addition to absorption forces to the great toe during weight bearing.

Etiology and Pathophysiology

- Trauma: stress fracture and acute fracture (hyperextension and axial loading of the metatarsophalangeal joint)
- Sesamoiditis: mechanical (repetitive trauma, cavus foot) or inflammatory disorders (infection, autoimmune disease)

Radiography

- Non-weight-bearing anteroposterior and lateral foot views
- Oblique views: a lateral 40° oblique view (for assessment of the fibular sesamoid) (Fig. 28) and a medial 40° oblique radiograph (for assessment of the tibial sesamoid)
- An axial view of the first metatarsophalangeal joint → may identify fractures in the sagittal plane not visible on the AP radiograph (Fig. 29)
- Bone scan: nonspecific as noted to be increased in 26–29 % of normal individuals
- CT scan: able to reveal irregular fracture margins in acute or early stress fractures
- MRI: marrow edema noted in stress fractures. Avascular necrosis (lack of signal intensity) (Fig. 30). Very useful in the setting of turf toe to identify the presence of articular injury, complete tear of the plantar plate (Fig. 31).

Classification

Turf Toe

- Grade 1: strain of the capsule without loss of continuity. Normal range of motion with ability to bear weight
- Grade 2: partial tear of the capsule. Limited and painful range of motion
- Grade 3: complete tear with loss of continuity of the plantar plate and capsule or associated sesamoid fracture. Inability to bear weight, limited range of motion, severe swelling, and ecchymosis

Fig. 28 Oblique view of the foot demonstrating a linear lucency within the fibular sesamoid (*arrow*). This is consistent with an acute fracture and not a bipartite sesamoid. The fibular sesamoid is rarely bipartite in isolation, and the irregular line is consistent with a fracture

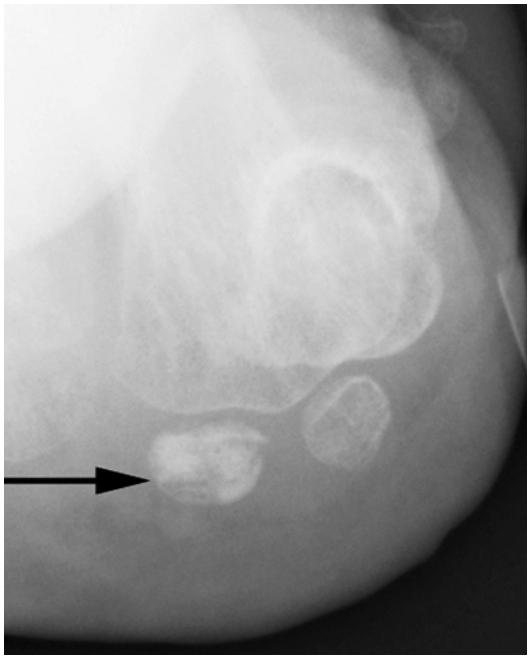

Fig. 29 Sesamoid views allow visualization of the metatarsal-sesamoid articulation. This view clearly demonstrates sclerosis (*arrow*), flattening, arthritis, and fracture

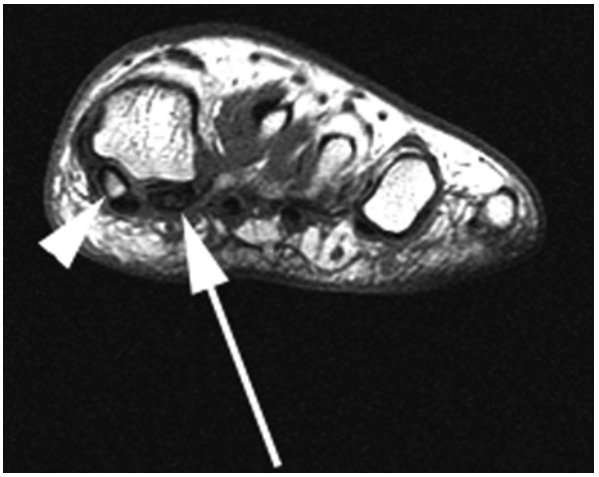

Fig. 30 Coronal T1 image of a patient with osteochondritis of the fibular sesamoid. Osteochondritis will appear as dark (*arrow*), in contrast to the normal bone that appears bright on T1 imaging (*arrowhead*)

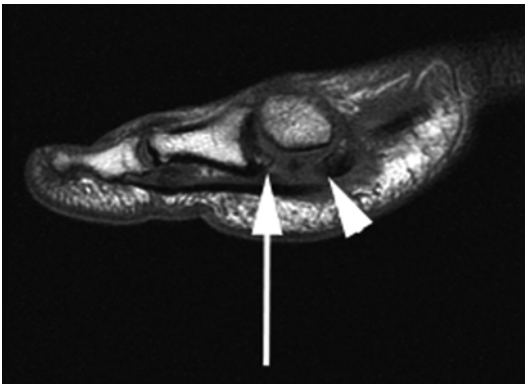

Fig. 31 Sagittal T1 image of an acute grade 3 turf toe injury. Note the disruption of the distal attachment of the plantar plate (*arrow*) with proximal retraction of the sesamoids (*arrowhead*)

Treatment

Turf Toe

- Grade 1: stiff insole with immediate return to play
- Grade 2: activity restriction for 2 weeks along with a stiff insole
- Grade 3: up to 6 weeks of rest and immobilization with return to play after 60° of painless dorsiflexion in patients without radiographic abnormality. Operative management for patients who do not respond to the above protocol or any radiographic abnormality (sesamoid migration, hallux valgus, sesamoid fracture, diastasis of bipartite sesamoid, articular impaction)

Sesamoiditis: mild to moderate pain can be controlled with anti-inflammatory medication, a stiff-soled or rocker-bottom shoe, and a dancer's pad (C-shaped pad with a relief for the sesamoids). Severe cases or fracture are treated with a CAM walker for 6 weeks followed by use of a dancer's pad and activity restriction until resolution of pain. Shoe wear modification (avoidance of high-heeled shoes) is also required.

Fig. 32 Plantar medial and plantar lateral incisions for repair of a Grade 3 turf toe injury

Fig. 33 Plantar medial approach to the tibial sesamoid must be undertaken carefully to avoid injury to the plantar medial digital nerve (pictured)

Operative
Turf Toe

- Dual incision technique to repair the plantar plate (Fig. 32). Avoid damage to plantar medial digital nerve (tibial sesamoid) and plantar lateral digital nerve (fibular sesamoid) (Fig. 33). Repair plantar plate directly or via bony tunnel through the distal aspect of the sesamoid (Fig. 34).

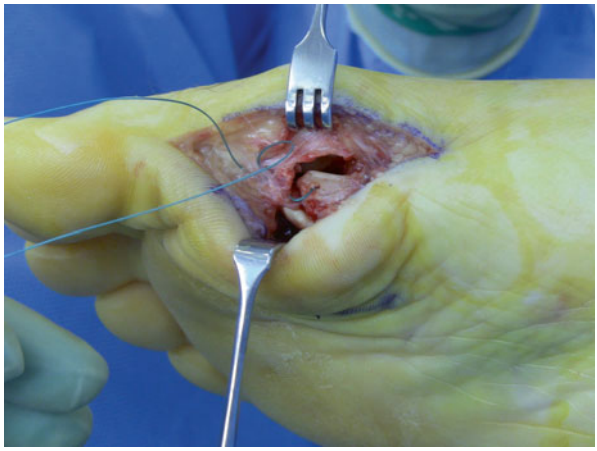

Fig. 34 Bone tunnel made within the distal aspect of the tibial sesamoid to allow fixation to the proximal aspect of the remaining plantar plate

Fig. 35 Severe cock-up deformity occurred after excision of both the medial and lateral tibial sesamoids

Chronic sesamoid pain (sesamoiditis, AVN, fracture).

- Complete or partial sesamoidectomy. Partial sesamoidectomy for a proximal or distal pole fracture. Repair of the FHB is critical to prevent complications of a coronal plane deformity. Ninety percent of patients will be able to return to pre-injury level of activity.

- Curettage and grafting of long-standing symptomatic nonunion has been described and, however, has not been proven to be superior to excision and is not the most reliable procedure.
- Excision of both the tibial and fibular sesamoid is not routinely performed secondary to the known complication of cock-up toe.

Complications

- Cock-up deformity: increased incidence after excision of both sesamoids (Fig. 35)
- Hallux valgus: related to excision of the tibial sesamoid
- Hallux varus: related to excision of the fibular sesamoid
- Chronic pain and neuroma formation at the surgical incision site with the plantar approach to the sesamoids

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