

Lesser toe deformities

Anatomy & Pathophysiology

MUSCULOTENDINOUS ANATOMY

- The extensor digitorum longus muscle originates from the tibia and fibula and inserts into the middle and distal phalanges of the lesser toes [2].
- The flexor digitorum longus muscle originates from the tibia and inserts into the distal lesser phalanges [2].
- The extensor digitorum longus is innervated by the deep peroneal nerve [2].
- The flexor digitorum longus is innervated by the tibial nerve [2].
- The extensor digitorum longus acts to dorsiflex the toes [2].
- The flexor digitorum longus acts to plantar flex the lesser toes [2].
- The extensor digitorum brevis is the only dorsal intrinsic muscle of the foot [15].
- The extensor digitorum brevis is innervated by the lateral terminal branch of the deep peroneal nerve [15].
- Lumbrical muscles are located plantar to the transverse metatarsal ligament [15].
- Interosseous tendons are located dorsal to the transverse metatarsal ligament [15].

NEUROVASCULAR ANATOMY

- The dorsalis pedis artery is a continuation of the anterior tibial artery that passes deep under the inferior extensor retinaculum [9].
- As the dorsalis pedis artery passes anterior to the ankle joint, it lies between the tendons of the extensor hallucis longus medially and the extensor digitorum longus laterally [9].
- The deep peroneal nerve lies immediately lateral to the dorsalis pedis artery [9].
- The arcuate artery arises from the dorsalis pedis artery in the region of the bases of the metatarsals and passes laterally [9].
- The second, third, and fourth dorsal metatarsal arteries arise from the arcuate artery and descend to the dorsal surfaces of the respective dorsal interosseous muscles [9].
- The first dorsal metatarsal artery is the continuation of the dorsalis pedis artery [9].

- The first dorsal metatarsal artery runs distally, usually on the dorsal surface of the first dorsal interosseous muscle [9].
- The first dorsal metatarsal artery supplies branches to the dorsal skin, the first and second metatarsals, and the interosseous muscles [9].
- Near the first web space between the first and second toes, the first dorsal metatarsal artery divides into at least two branches [9].
- One branch of the first dorsal metatarsal artery passes deep to the tendon of the extensor hallucis longus to supply the medial side of the great toe [9].
- The other branch of the first dorsal metatarsal artery divides to supply the adjacent sides of the great and second toes [9].
- The deep plantar, or communicating, artery leaves the dorsalis pedis at the base of the first metatarsal [9].
- The deep plantar artery passes toward the plantar surface of the foot between the heads of the first dorsal interosseous muscle [9].
- The deep plantar artery communicates with the lateral plantar artery to complete the plantar arterial arch [9].
- The deep plantar artery supplies a branch to the medial side of the great toe [9].
- The first plantar metatarsal artery is the continuation of the deep plantar artery [9].
- The first plantar metatarsal artery passes distally in the first interosseous space and divides to supply the adjacent sides of the great and second toes from the plantar side [9].
- In 78% to 88% of feet, the first dorsal metatarsal artery lies superficial to or just within the substance of the first dorsal interosseous muscle [9].
- In 12% to 22% of feet, the first dorsal metatarsal artery lies plantar to the first metatarsal [9].
- The venous drainage from the dorsum of the toes and foot flows into the dorsal venous arches, feeding the greater and lesser saphenous systems [9].
- Additional venous drainage from the dorsum of the foot occurs through the veins accompanying the dorsalis pedis artery [9].
- The dorsal surfaces of the toes and foot receive sensory innervation through the superficial peroneal nerve branches [9].
- The first web space is innervated by the deep peroneal nerve [9].
- The plantar surface of the foot is innervated by the digital branches of the medial plantar nerve [9].

PATHOPHYSIOLOGY OF LESSER TOE DEFORMITIES

- Deformities of the lesser toes result from an imbalance between the intrinsic and extrinsic musculotendinous units of the toes [5].
- With hyperextension at the metatarsophalangeal (MTP) joint, the strong flexors overpower the intrinsic extensors of the interphalangeal (IP) joints [5].

- The overpowering of intrinsic extensors by strong flexors results in flexion deformities at the IP joints and extension deformities at the MTP joints [5].
- Lesser MTP deformity starts with dysfunction of the plantar plate [5].
- Mallet toe is defined as a hyperflexion deformity at the distal interphalangeal (DIP) joint [5].
- Hammer toe is defined as a flexion deformity at the proximal interphalangeal (PIP) joint and an extension deformity at the MTP and DIP joints [5].
- Claw toe is defined as an extension deformity at the MTP joint combined with hyperflexion at the PIP and DIP joints [5].
- The difference between a hammer toe and a claw toe is the positioning of the DIP joint [5].
- As claw toe develops, flexor tendons pull the IP joints into flexion and the MTP joint into extension [5].
- The pulling of the MTP joint into extension depresses the metatarsal head and pulls the plantar fat pad distally [5].
- Depression of the metatarsal head and distal migration of the plantar fat pad result in metatarsalgia, callus, or ulcer formation [5].
- The primary deficiency at the MTP joint level in claw toe is dysfunction or tearing of the plantar plate [5].
- The plantar plate usually holds the base of the phalanx in alignment with the metatarsal head [5].
- Bunionette deformity, or tailor's bunion, is defined as a prominence of the lateral aspect of the fifth metatarsal head [5].
- Bunionette deformity causes pain over the lateral or plantar aspect of the MTP joint, particularly with compressive footwear [3].
- Three distinct types of bunionette deformity are described based on the anatomic location of the deformity along the fifth metatarsal [3].
- Type I bunionette deformity is distinguished by the presence of an enlarged fifth metatarsal head [3].
- Type II bunionette deformity demonstrates lateral bowing of the fifth metatarsal diaphysis [3].
- Type III bunionette deformity demonstrates an abnormally widened fourth–fifth metatarsal angle [3].
- The normal fourth–fifth metatarsal angle is less than 8 degrees [3].
- Bunionette deformity in conjunction with ipsilateral hallux valgus and metatarsus primus varus is termed splayfoot [3].
- Cavus foot is a foot with an abnormally high arch [1].
- Cavus foot frequently accompanies hindfoot varus deformity, known as cavovarus foot [1].
- Cavovarus foot may be associated with clawing of the toes and demonstrable weakness of ankle or foot muscles [1].
- Calluses beneath the metatarsal heads and heel skin are common in cavus foot [1].
- The cause of cavus foot is usually muscle imbalance in a growing foot [1].
- Cavus is rarely found in early childhood but is fairly frequent after 8–10 years of age [1].
- Intrinsic muscle weakness is a major cause of cavus foot [1].

- Weakness of the peroneal or anterior tibialis muscles is also implicated in the cause of cavus foot [1].
- Cavus foot is rarely found in the absence of an underlying neuromuscular condition [1].
- Cavus foot is a marker for neuromuscular disease [1].
- In cavus foot, the forefoot is severely plantar flexed on the hindfoot, requiring marked ankle dorsiflexion to compensate [1].
- When cavus becomes too severe, ankle dorsiflexion is blocked, leading to anterior ankle impingement and pain [1].
- The inability to dorsiflex further compromises forefoot clearance, eventually allowing only the metatarsals to contact the floor [1].
- This condition can be misinterpreted as ankle plantarflexion contracture, leading to unnecessary heel cord release [1].
- Hallux valgus is defined as lateral deviation of the great toe with medial deviation of the first metatarsal [7].
- The pathophysiology of hallux valgus is likely multifactorial [7].
- Intrinsic factors contributing to hallux valgus include genetic predisposition, ligamentous laxity, and predisposing anatomy such as a convex metatarsal head or pes planus [7].
- Extrinsic factors contributing to hallux valgus include certain types of footwear, such as narrow toe boxes and high heels [7].
- The pathoanatomy of hallux valgus involves medial capsular attenuation [7].
- In hallux valgus, the proximal phalanx drifts laterally [7].
- Lateral drift of the proximal phalanx leads to plantar-lateral migration of the abductor hallucis [7].
- Plantar-lateral migration of the abductor hallucis causes the proximal phalangeal unit to plantar flex and pronate the hallux [7].
- The pronation of the hallux is amplified by the proximal phalangeal attachment of the adductor hallucis [7].
- Lateral deviation of the extensor hallucis longus and flexor hallucis longus causes a muscular imbalance and deforming force for valgus progression and pronation of the great toe [7].
- In hallux valgus, the first metatarsal head moves medially off the sesamoids, increasing the intermetatarsal angle [7].
- Pronation in hallux valgus leads to rounding of the lateral metatarsal head, which should have a flat contour with no rotational deformity [7].
- Secondary contracture occurs in the lateral capsule, adductor hallucis, and lateral metatarsal-sesamoid and intermetatarsal ligaments in hallux valgus [7].
- The pathoanatomy of hallux valgus involves gradual failure of the medial supportive structures, including the medial collateral ligament and tibial sesamoid, resulting in a varus position of the first metatarsal [28].
- Valgus deviation at the MTP joint of the proximal phalanx subsequently develops as hallux valgus progresses [28].

- As hallux valgus progresses, the alignment of the flexor and extensor hallucis longus tendons shifts laterally relative to the MTP joint, further exacerbating the deformity [28].
- First metatarsal varus results in a prominent first metatarsal head medially, which is the bump or “bunion” reported by the patient [28].
- Secondary pathology and deformity can develop in the lesser toes, such as hammertoes and claw toes, in patients with hallux valgus [28].
- The etiology of hallux valgus is a combination of intrinsic factors such as genetic predisposition or a hypermobile first tarsometatarsal joint, and extrinsic factors predominantly related to high-heeled shoes with a narrow toe box [28].
- Other predisposing factors for hallux valgus include rheumatoid or inflammatory arthritis, generalized ligamentous laxity, and dysmorphism of the first metatarsal [28].
- Hallux valgus deformity is usually progressive, although the rate and degree of progression is often nonlinear [28].
- Hallux valgus is most commonly seen in female patients in their fourth or fifth decades of life [28].
- Adolescent bunion is frequently hereditary and usually seen in early adolescence [32].
- Adolescent bunion is almost always found in conjunction with a wide forefoot caused by varus (medial deviation) of the first metatarsal shaft, known as metatarsus primus varus [32].
- The wide forefoot in adolescent bunion allows severe lateral deviation of the great toe, causing the prominent base of the great toe to rub against the inside of the shoe and create a painful bunion [32].
- Many adolescent bunions are progressive and require surgical management [32].
- Surgery for adolescent bunion must address each aspect of the deformity, including trimming the bunion, correcting the varus angulation of the first metatarsal by osteotomy, and centralizing and balancing the hallux valgus by lengthening the adductor hallucis muscle [32].
- There is a fairly high incidence of recurrence of adolescent bunion deformity following surgery [32].

COMPARTMENT ANATOMY

- Most authorities previously believed there were four compartments in the foot: medial, lateral, central, and interosseous [14].
- The medial compartment lies on the plantar surface of the hallux [14].
- The lateral compartment is on the plantar surface of the fifth metatarsal [14].
- The central compartment lies on the plantar surface of the foot [14].
- The interosseous compartment lies dorsal to the others between the metatarsals [14].
- The medial compartment contains the intrinsic muscles of the great toe and flexor digiti minimi [14].
- The lateral compartment contains the abductor digiti minimi [14].
- The superficial central compartment contains the flexor digitorum brevis [14].
- The deep (calcaneal) central compartment contains the quadratus plantae [14].
- The adductor hallucis compartment contains the adductor hallucis [14].

- The interosseous compartments contain the interosseous muscles and digital nerves [14].
- Manoli and Weber challenged the concept of four compartments using cadaver infusion techniques, proposing nine compartments in the foot [14].
- The nine-compartment model includes two central compartments: one superficial containing flexor digitorum brevis, and one deep (calcaneal) containing quadratus plantae [14].
- The deep calcaneal compartment communicates with the deep posterior compartment of the leg [14].
- Each of the four interosseous muscles and the adductor hallucis lies in separate compartments in the nine-compartment model [14].
- The barrier between the superficial and calcaneal compartments becomes incompetent at a pressure of 10 mm Hg [14].
- A pressure of 10 mm Hg is much lower than that required to produce an acute compartment syndrome [14].

TARSAL TUNNEL ANATOMY

- The tarsal tunnel is a fibroosseous tunnel within the posteromedial ankle and hindfoot [6].
- The tibial nerve, posterior tibial artery, accompanying veins, posterior tibial tendon, flexor digitorum longus, and flexor hallucis longus tendons pass into the foot through the tarsal tunnel [6].
- The flexor retinaculum acts as the roof of the tarsal tunnel and extends from the medial malleolus to the medial side of the calcaneal tuberosity [6].
- The medial distal tibia, talus, and calcaneus make up the floor of the tarsal tunnel [6].
- Septa that separate the posterior tibial, flexor digitorum longus, and flexor hallucis longus tendons project from the fibrous roof to the calcaneus [6].
- Between the flexor digitorum longus and flexor hallucis longus tendons, the tibial nerve, posterior tibial artery, and accompanying veins pass to enter the foot [6].
- Before reaching the foot, the tibial nerve divides into three terminal branches: the medial calcaneal nerve, lateral plantar nerve, and medial plantar nerve [6].
- Typically, the tibial nerve branches within the tunnel just proximal and deep to the upper edge of the abductor hallucis muscle [6].
- The medial calcaneal nerve branches first, traveling posteriorly to the subcutaneous tissue [6].
- The first branch of the lateral plantar nerve passes under the abductor, over the medial fascia of the quadratus plantae, deep to the plantar fascia, and under the heel to the flexor digitorum brevis [6].
- The first branch of the lateral plantar nerve sends a sensory branch to the central heel skin and terminates in the abductor digiti quinti [6].
- Anterior to its first branch, the lateral plantar nerve passes deep to the abductor fascia and plantar fascia and over the quadratus plantae [6].
- The lateral plantar nerve continues distally under the flexor digitorum brevis, terminating in the fourth web space and supplying a branch to the third web space [6].

- The lateral plantar nerve supplies motor branches to the intrinsic muscles [6].
- The medial plantar nerve innervates the abductor and continues under the abductor and the plantar fascia to form the common digital nerves [6].
- The common digital nerves terminate to the first, second, and third web spaces and provide motor branches to the interossei and lumbricals [6].
- Historically, tarsal tunnel syndrome referred to tibial nerve entrapment beneath the flexor retinaculum [6].
- Distal tarsal tunnel syndrome involves entrapment of the distal tibial nerve branches as they enter the foot [6].
- Sources of constriction beneath and adjacent to the tarsal tunnel include bone fragments, tenosynovitis, ganglia, soft-tissue encroachment in inflammatory arthritis, varicosities, neural tumors, perineural fibrosis, tarsal coalition, and calcaneal osteotomies [6].
- A fixed valg

Investigations

GENERAL IMAGING PRINCIPLES

- Weight-bearing anteroposterior, lateral, and oblique views of the foot are included in the radiographic evaluation for metatarsalgia [30].
- The skyline view of the metatarsal heads, obtained with the metatarsophalangeal joints in dorsiflexion, is helpful to evaluate overall alignment and demonstrate the height of the metatarsal heads [30].
- Magnetic resonance imaging (MRI) can be useful in the diagnosis of metatarsalgia to distinguish among a neuroma, cyst, bursa, or synovitis [30].
- MRI is a fundamental tool in the workup of a patient with a soft-tissue or bone tumor in the foot [34].
- Focused MRI imaging of the metatarsophalangeal joints can detect sesamoid pathology and plantar plate injuries [34].
- MRI is a valuable imaging modality in the evaluation of patients with suspected bone or soft-tissue infection, detecting osteomyelitis well before radiographic abnormalities are visible [34].
- In neuropathic patients, the specificity of MR signal abnormalities for osteomyelitis is reduced [34].
- Normal MRI marrow signal confidently excludes osteomyelitis in the foot [34].
- The addition of contrast-enhanced MRI sequences is helpful in defining nonenhancing fluid collections, abscesses, and devascularized or gangrenous tissue [34].
- Computed tomography (CT) scans are important in assessing fractures and for congenital bony coalitions [29].
- Radio-isotope scanning is excellent for localizing areas of abnormal blood flow or bone remodelling activity, which suggest the presence of covert infection [29].
- Magnetic resonance imaging (MRI) and ultrasound are used to demonstrate soft-tissue problems, such as tendon and ligament injuries, and can diagnose joint effusions and bone infections [29].

- Stress X-rays complement clinical tests for ankle stability and can be carried out under general anaesthesia if stress manoeuvres are painful [29].

SPECIFIC PATHOLOGY IMAGING

- Ultrasonography has been reported to be 85% accurate in diagnosing interdigital neuroma [25].
- MRI may be useful for diagnosing interdigital neuroma, and the administration of contrast medium may increase its accuracy [25].
- Injection of the involved web space with local anesthetic that results in relief of neuritic symptoms is diagnostic of interdigital neuroma [25].
- Injections performed under ultrasound guidance for interdigital neuroma have higher short-term relief compared with blind injections [25].
- Weight-bearing radiographs are useful for excluding a stress fracture of the metatarsal neck in the evaluation of interdigital neuroma [25].
- Interdigital or Morton neuroma is most frequently found in the distal third metatarsal interspace on MRI [34].
- Unlike most other tumors, interdigital neuroma lacks increased signal on T2-weighted MRI sequences [34].
- Plantar fibroma or plantar fibromatosis is usually confirmed by the presence of a signal-poor mass arising from the plantar fascia on MRI [34].

NEUROMUSCULAR AND DEFORMITY WORKUP

- Diagnosis of cavus foot requires a thorough search for the underlying cause and may require neurologic consultation, spinal MRI, and electromyographic (EMG) studies [1].
- A neurologic examination and a family history are essential in the evaluation of pes cavus [36].
- MRI of the spine is indicated with unilateral involvement in pes cavus [36].
- Hindfoot flexibility in pes cavus is assessed by placing a 1-inch block under the lateral border of the foot (Coleman block test) [36].
- Weight-bearing radiographs are required for the evaluation of pes cavus [36].
- An increased Meary angle, where the long axis of the talus intersects the long axis of the first metatarsal dorsally on the lateral view, is a radiographic finding in pes cavus [36].
- The normal value for the Meary angle is 0° to 5° [36].
- An increased calcaneal pitch, defined as the intersection of a line running along the undersurface of the calcaneus and the floor, is a radiographic finding in pes cavus [36].
- A calcaneal pitch greater than 30° indicates a calcaneocavus foot [36].

Treatment

NON-OPERATIVE

- Shoewear modification, strategic padding, and shaving of the symptomatic callus are usually effective for bunionette deformity [3].
- With plantar callus or associated pes planus, a metatarsal pad or custom orthotic device should be considered for bunionette deformity [3].
- Nonsurgical treatment for mallet toe includes wearing shoes with high toe boxes and using foam or silicone gel toe sleeves or crest pads [5].
- Nonsurgical treatment for hammer toe includes wearing shoes with high toe boxes and using foam or silicone gel toe sleeves [5].
- Initial nonsurgical treatment for claw toe is aimed at shoe-wear modification, with adequate plantar padding (including metatarsal pad inserts) and a shoe with a high toe box [5].
- Crest pads may be used for the nonsurgical management of claw toe [5].
- Steroid injections have very limited indications for claw toe and should be used judiciously [5].
- Steroid injections for claw toe frequently result in weakening of the collateral ligaments and plantar plate resulting in progression and worsening of the deformity [5].

OPERATIVE: BUNIONETTE

- Lateral metatarsal head condylectomy is the surgical treatment for type I bunionette deformity [3].
- Distal fifth metatarsal osteotomy (i.e., chevron) is the surgical treatment for type II bunionette deformity [3].
- Oblique diaphyseal osteotomy is the surgical treatment for type III bunionette deformity [3].
- Metatarsal head resection should be considered for salvage in bunionette deformity [3].
- Proximal osteotomy should be avoided for bunionette deformity owing to the tenuous blood supply at the proximal metadiaphyseal junction of the fifth metatarsal [3].

OPERATIVE: MALLET TOE

- A flexible mallet toe deformity can be corrected with a percutaneous release of the FDL tendon at its insertion into the base of the distal phalanx [5].
- In fixed mallet toe deformity, surgical correction involves resection of the distal condyles of the middle phalanx and repair of the extensor tendon combined with temporary wire fixation [5].
- Recurrent MTP joint instability after surgical correction of mallet toe is usually a result of persistent plantar plate dysfunction [5].

OPERATIVE: HAMMER TOE

- Surgery for hammer toe is indicated when nonsurgical treatment does not provide adequate relief of symptoms [5].
- In the absence of MTP pathology, surgical correction of hammer toes involves resection of the distal condyles of the proximal phalanx of the toe [5].
- Resection for hammer toe may be combined with an FDL tenotomy, performed either via the dorsal incision used for the condylar resection or through a plantar percutaneous release [5].
- The toe should be pinned with temporary wire fixation during hammer toe correction [5].
- Newer permanent implants are available to eliminate the need for K-wire fixation in hammer toe surgery [5].
- Numerous studies have shown only minimal improvement in satisfaction without improvement in clinical outcomes, but at a significantly higher cost for the implants used in hammer toe surgery [5].
- If the MTP joint is involved in hammer toe deformity, correction is the same as that for claw toe deformity [5].

OPERATIVE: CLAW TOE

- The MTP imbalance in claw toe is addressed with an extensor tendon Z-plasty lengthening and MTP capsular release [5].
- Extensor tendon Z-plasty lengthening and MTP capsular release may be combined with a distal oblique metatarsal shortening osteotomy when associated with a long second metatarsal [5].
- Extensor tendon Z-plasty lengthening and MTP capsular release may be combined with a FDL-to-EDL (Girdlestone-Taylor) tendon transfer to achieve balance of the affected MTP joint [5].
- Newer procedures for claw toe include repairing the plantar plate at the proximal phalanx plantar insertion [5].
- In plantar plate repair for claw toe, the plantar plate is captured with a nonabsorbable suture using a suture passer system [5].
- In plantar plate repair for claw toe, the suture is passed through drill holes in the base of the proximal phalanx and tied dorsally with the toe positioned in slight plantar flexion [5].
- When there is a crossover component to claw toe deformity, the damaged collateral ligament is repaired with nonabsorbable suture [5].
- The hammer toe and mallet toe components of claw toe deformity are corrected via a proximal phalangeal distal condylar resection and FDL tenotomy [5].
- A wire is placed across the DIP, PIP, and MTP joints for temporary stabilization during claw toe correction [5].
- Persistent plantar plate dysfunction may result in recurrence of claw toe deformity [5].

OPERATIVE: AXIAL PLANE DEFORMITY

- In the mildest cases of varus or valgus deformity, simple release of the contracted collateral ligament may be all that is necessary [37].
- Imbrication of the opposite side may provide an additional measure of correction for mild varus or valgus deformity [37].
- Satisfactory results have been reported with the use of the extensor digitorum brevis tendon rerouted underneath the transverse metatarsal ligament for varus deformity [37].
- A competent intermetatarsal ligament is a prerequisite for the extensor digitorum brevis tendon rerouting procedure [37].
- Ellis et al. described an extensor digitorum brevis reconstructive technique combined with a medial collateral ligament and partial plantar plate release for correction of multiplanar deformity of the second metatarsophalangeal joint [37].
- A shortening osteotomy of the metatarsal may be necessary to correct the deformity and instability of the metatarsophalangeal joint [37].
- A shortening osteotomy of the metatarsal will prevent the use of the extensor digitorum brevis transfer [37].
- Klinge et al. described a modification of the Weil osteotomy to address varus or valgus angulation of the toe not corrected with simple ligament balancing [37].
- The modified Weil osteotomy is considered particularly successful and powerful in procedures involving varus or valgus angulation of the toe not corrected with simple ligament balancing [37].
- Joseph et al. reported a statistically significant reduction in pain, improvement in alignment, and full return to unrestricted weight-bearing activities in 31 patients with metatarsophalangeal joint fusions [37].
- Complications of metatarsophalangeal joint fusions reported by Joseph et al. included 13% with nonunions, 6% with implant breakage, and 3% with soft-tissue infection [37].

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