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Review Article

Great Toe Anatomy

King MA, Vesely BD* and Teasdall RD
Department of Orthopaedic Surgery, Wake Forest Baptist Medical Center, Winston Salem, NC, USA

***Corresponding author:** Bryanna D Vesely, Department of Orthopaedic Surgery, Wake Forest Baptist Medical Center, Oakwood Ct. Winston Salem, NC, 27103, USA

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Abstract

In conclusion, hallux abductovalgus is a common deformity of the forefoot that has complex implications on the biomechanics and gait of patients. Understanding the anatomy and physiology behind this deformity is essential when creating conservative and surgical treatment plans.

Keywords: Anatomy; Hallux; Great toe; Toot; Podiatry; Sesamoid; Bunion; Hallux valgus

Introduction

Anatomy is the foundation of medicine. It is the first subject taught in medical training and it creates the groundwork for advanced physiology and pathology. When diagnosing and treating a patient, it is essential to have an advanced knowledge base of anatomy in order to correctly reach a diagnosis. Due to the complexity of the first ray structure, it can be difficult to accurately diagnose and treat this part of the body. Therefore, it is important for practitioners of any level to review human anatomy. The purpose of this article is to review great toe anatomy and its most common deformity: hallux abductovalgus.

Hallux abductovalgus is the most common forefoot pathology in adults. Nix et al performed a systematic review and meta-analysis estimating hallux valgus prevalence in 23% of adults aged 18-65 and 36.7% in elderly people over the age of 65 [1]. Hallux valgus has a predilection for women; as high as 15:1 in some studies [1]. It can be defined as a progressive deformity beginning with a lateral deviation of the great toe, medial deviation of the first metatarsal, and progressing to first metatarsophalangeal subluxation [3]. Previous studies have shown a genetic correlation, finding that up to 90% of patients with painful hallux abductovalgus deformities have some family members with a similar deformity [2]. Other causes of hallux valgus include restrictive foot wear, neuromuscular disorders, and other foot deformities such as pes planus, equinus, and ligament laxity [3].

Symptoms for hallux valgus include pain, wearing shoes with narrow toe boxes, pain at the medial eminence of the first metatarsal, and pain during weight bearing. With progression of the deformity, patients may have pain during range of motion of the first metatarsophalangeal joint, pain during rest, and decreased range of motion at the 1st metatarsophalangeal joint. Conservative treatments include wide toe box shoes, orthotics, and toe padding. Surgical treatment is complex and chosen based on the complexity of the deformity and the goals of the patient. For less severe deformities, more distal procedures can be performed while proximal osteotomies are done for severe deformities. There is estimated to be more than 150 different hallux abductovalgus procedures [4]. It is essential to understand the great toe anatomy when performing hallux abductovalgus procedures in order to understand the biomechanical impacts of the foot and chose the proper surgery.

Bones

The great toe includes five bones: the first metatarsal, proximal phalanx, distal phalanx, tibial sesamoid, and fibular sesamoid (Figure 1).

The first metatarsal base is triangular shaped with a reniform shaped articular cartilage articulating with the medial cuneiform [6]. The articular surface measures an average of 32.3mm from dorsal to plantar [7]. A tubercle sits on the medial surface of the base where the tibialis anterior tendon inserts, while a more prominent tubercle sits on the lateral surface at the site of peroneus longus insertion. The shaft is the shortest and strongest of the metatarsals. It has three surfaces including dorsomedial, lateral, and inferior. The inferior surface has a longitudinally concave contour [8]. The head is quadrilateral in shape and has a smooth convex shape with a dorsal border that overhangs the shaft. The plantar surface contains a rounded ridge called the crista oriented anteroposteriorly separating the surface into two slopes. The crista is not centrally located but rather one third from the lateral border. The slopes house the sesamoids with the medial groove

Figure 1: [5].

Figure 2: [9].

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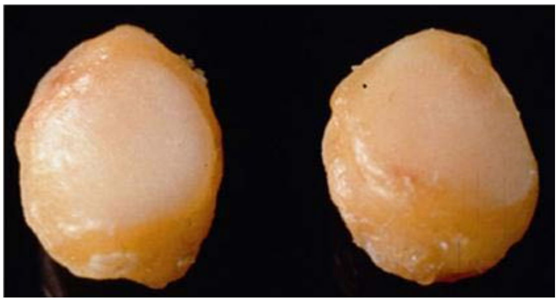

Figure 3: [12].

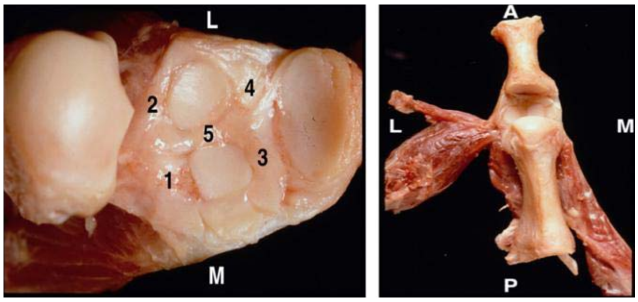

Figure 4: [16].

deeper than the lateral (Figure 2).

The sesamoids (medial and lateral or tibial and fibular) are small round bones which are convex from medial to lateral and concave from anterior to posterior (Figure 3). The sesamoids can best be thought of as saddle shaped. They are embedded in the thick plantar plate and assist in the gliding mechanism of the great toe joint. Bipartite sesamoids may be a variation of normal anatomy. It has been estimated that 14.6% of feet have at least one partite sesamoid, most frequently the medial sesamoid [10]. Bipartite sesamoids may be confused with a single sesamoid with fracture. Some characteristics of a bipartite sesamoid include two corticated components, the two components do not fit together, and no MRI signal abnormality [11].

The proximal phalanx has a large, ovoid base with a glenoid concave cavity smaller than the metatarsal head. There is a central boney prominence on the dorsum of the base where the extensor hallucis brevis inserts. Plantarly, there are two tubercles both medially and laterally. The medial head of the flexor hallucis brevis and abductor hallucis insert medially while the lateral head of the flexor hallucis brevis and adductor hallucis insert laterally. The plantar plate inserts firmly on the plantar border of the base. The shaft is convex dorsally and flat plantarly. At the head, there are tubercles dorsally where the collateral ligaments insert [13].

The distal phalanx has a transverse tubercle on the dorsum of the base where the extensor hallucis longus tendon inserts. The proximal position of the tendon allows for a large insertion of the ungual matrix to the dorsum of the phalanx. The flexor hallucis longus inserts on the plantar shaft.

Ligaments

Ligaments are short tough bands of flexible fibrous tissue which connect bone to bone. Of note, ligaments have very poor blood supply when compared to muscle or bone [14]. The great toe includes the capsular ligaments of both the Metatarsophalangeal (MTP) and Interphalangeal (IP) joints, the plantar plates of the MTP and IP joints, the collateral metatarsophalangeal ligaments, the metatarsosesamoid suspensory ligaments, and the collateral interphalangeal ligaments. The capsular ligaments enclose the joint, holding in joint fluid; a viscous liquid that allows fluid repetitive motion. The plantar plate of the MTP joint differs from the lesser MTP joints and was described by Gillette in 1872 as the semsamoidphalangeal apparatus [15]. This structure houses the sesamoids and inserts into the plantar base of the proximal phalanx of the hallux. The apparatus is divided into 5 ligaments: medial (1) and lateral (2) metatarsosesamoid ligaments, medial (3) and lateral (4) phalangeosesamoid ligaments, and the intersesamoid ligament (5) (Figure 4).

Muscles

The great toe has seven different muscles acting at one time (Figure 5). Three intrinsic muscles are located plantarly and all insert into the base of the proximal phalanx. The abductor hallucis runs along the medial border of the foot, from the tuberosity of the calcaneus to the medial base of the proximal phalanx of the hallux, and is located in the first layer of plantar muscles. It abducts and aids in plantarflexion of the hallux and is innervated by the medial plantar nerve. The Flexor Hallucis Brevis (FHB) has both a medial and lateral arm at its origin and insertion. The medial arm originates on the plantar component of the posterior tibial tendon. At the insertion, the medial tendon contains the medial sesamoid and blends with the plantar plate and the tendon of abductor hallucis inserting at the plantar base of the proximal phalanx. The lateral arm originates from the plantar surface of the cuboid and lateral cuneiform. At the insertion, the lateral tendon contains the lateral sesamoid and blends with the plantar plate and the conjoined tendon of the adductor hallucis inserting at the plantar base of the proximal phalanx. The FHB plantarflexes the proximal phalanx of the hallux and is located in the third layer of plantar muscles. It is innervated by the medial plantar nerve. The adductor hallucis has both an oblique and transverse head. The oblique head originates on the plantar surface of the bases of the 2nd,

Figure 5: [16].

3rd and 4th metatarsals and the tendon sheath of the peroneus longus. The transverse head originates on the plantar plates of the 3rd, 4th and 5th MTPs and the deep transverse metatarsal ligament between the metatarsal heads. The two heads then unite to form a conjoined tendon that courses through a split in the deep transverse metatarsal ligament. The tendon blends with the lateral tendon of FHB, the lateral sesamoid, and the plantar plate and inserts into the lateral aspect of the base of the proximal phalanx of the hallux. The adductor hallucis adducts and aids in plantarflexion of the hallux. It is located in the third layer of plantar muscles and is innervated by the deep branch of the lateral plantar nerve.

The Extensor Hallucis Brevis (EHB) is an intrinsic muscle on the dorsum of the foot which originates from the sinus tarsi of the calcaneus, the interosseous talocalcaneal ligament, and the inferior extensor retinaculum. The EHB courses obliquely from lateral to medial and inserts on the dorsal base of the proximal phalanx of the hallux. The EHB dorsiflexes the proximal phalanx of the hallux and is innervated by the lateral terminal branch of the deep peroneal nerve.

The extensor hallucis longus (EHL) is housed in the anterior compartment of the leg and originates from the middle portion of the medial shaft of the fibula and interosseous membrane. It the courses in a synovial sheath beneath the superior and inferior extensor retinacula, forms the extensor hood of the first MTP, and then inserts at the dorsal base of the distal phalanx of the hallux. The EHL dorsiflexes the hallux at both the IP and MTP joints, dorsiflexes the foot, and is innervated by the deep fibular nerve.

The Flexor Hallucis Longus (FHL) is in the deep posterior compartment of the leg and originates from the middle and lower portions of the posterior fibula. The FHL courses inferior to the sustentaculum tali then distally within the second layer of muscles where it gives rise to the Knot of Henry. The FHL finally inserts at the plantar base of the distal phalanx of the hallux. The FHL plantarflexes the hallux at the IP and MTP joints, plantarflexes the foot, and is innervated by tibial nerve.

Blood Supply

The blood supply of the hallux stems from the dorsalis pedis, which turns into the first dorsal metatarsal artery and the posterior tibial artery, which turns into the medial plantar arch, and then into the first plantar metatarsal artery. The first metatarsal has a nutrient artery entering the lateral surface at the middiaphyseal level as well as metaphyseal arteries supplying both the base and head. Avascular necrosis can be a potential complication during first ray surgeries if blood supply is disrupted. Understanding the blood supply to the hallux is essential when choosing osteotomy location during hallux abductovalgus surgeries in order to preserve blood supply and reduce chances of comorbidities [17].

Clinical Significance

The great toe has a complex anatomy that is essential to the biomechanics of gait. Literature has estimated that between 20-30 % of ground reactive force goes through the great toe while ambulating [18]. In patients with hallux valgus deformities, the biomechanics of gait changes. In normal foot anatomy, in the terminal stance of gait, the load is transferred to the hallux and first metatarsal head. In patients with a hallux valgus deformity, it interferes with force propulsions and alters the pressures of the foot [19]. It has been shown that the hallux plantar pressures can increase in hallux valgus deformities from the altered alignment of the first ray [20]. Transfer lesions can also take place in hallux valgus deformities causing metatarsalgia of the lesser toes [21]. Hallux valgus can also change the structure of the foot. In a study comparing hallux valgus feet to normal feet, the transverse arch height was increased when compared to the control in all positions due to the displacement and rotation of the metatarsesamoid complex. Having an increased transverse arch impacts the biomechanics of the rest of the foot and gait [22].

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