The Simple Bunion: Anatomy at the Metatarsophalangeal Joint of the Great Toe

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ABSTRACT

The pathomechanics for the development of the hallux valgus deformity takes place at the first metatarsophalangeal joint—the sesamoid complex. The sesamoid complex consists of seven muscles, eight ligaments, and two sesamoid bones. When the first metatarsal escapes the complex and drifts medially, the sesamoids remain twisted in situ, several of the ligaments “fail,” and others contract. The authors propose reduction of the metatarsus primus varus by first metatarsal osteotomy and appropriate ligament releases and plications to restore alignment. A detailed understanding of the pathomechanics is essential for proper interpretation of the problems and anticipated lasting surgeries.

Dissection of the forefoot in the anatomy laboratory revealed that the pathomechanics for the development of the hallux valgus takes place at the first metatarsophalangeal joint—the sesamoid complex. The sesamoid complex consists of seven muscles, eight ligaments, and two sesamoid bones. The eight muscles are the adductor hallucis, the medial and lateral heads of the flexor hallucis brevis, the flexor hallucis longus, the adductor hallucis, extensor hallucis brevis, and the extensor hallucis longus. The eight ligaments are the medial sagittal hood, lateral sagittal hood, medial sesamoid, intersesamoid, medial collateral, lateral collateral, and transverse metatarsal ligaments.

When the first metatarsal head escapes the complex and drifts medially, the sesamoids remain twisted in situ next to the second metatarsal pad. Several of the ligaments become attenuated while others contract. As muscle imbalance becomes prominent, the adductor hallucis contracts, the adductor hallucis slips under the head of the first metatarsal and becomes to some degree a flexor, the long and short extensor tendons drift laterally and contract, the long flexor displaced laterally with the two sesamoids loses its power as a straight plantar flexor and the short flexor embedded in the two sesamoids creates an asymmetrical lateral pull to the great toe.

As the first metatarsal head drifts medially, it escapes the confines of the sesamoid complex. The medial sesamoid and medial collateral ligaments fail along with degeneration of the crista, the central prominence of the first metatarsal separating the two sesamoids. The lateral sesamoid and the lateral collateral ligaments contract. The intermetatarsal ligament is not the source of this pathological process.

The authors propose reduction of the metatarsus primus varus by first metatarsal osteotomy and appropriate ligament releases and plications to restore alignment. A detailed understanding of the pathomechanics is essential for proper interpretation of the problem and selection of lasting surgeries.

The authors claim no originality other than noting the splitting of the transverse metatarsal ligament to accommodate the adductor hallucis tendon on its way to insertion into the proximal phalanx of the great toe (Fig. 1). In our literature search we have found no mention of this anatomic variant. Currently, our anatomic dissections, only 20 in number, are insufficient to estimate a valid incidence rate, and the significance of this variant is largely speculative.

MATERIAL AND METHODS

Twenty anatomic dissections were carried out looking for common denominators in the anatomy of the first metatarsophalangeal joint. These included foot specimens from two patients under 20 years of age who suffered traumatic amputation. Twelve specimens were available as a result of amputation from failed revascularization procedures performed on patients with severe peripheral vascular disease. Of these, two had prominent hallux valgus and metatarsus primus...
varus and three had normal alignment. Variations from the apparent normal anatomy were appreciated. These findings were compared to the current literature to review the normal and pathological anatomy of the hallux valgus and sesamoid complex.

NORMAL ANATOMY

In order to fully understand the anatomy of the hallux valgus, one must first master the normal anatomy at the metatarsal phalangeal joint of the great toe. The focus will be upon the sesamoids and their ligaments, the thick fibrous plantar plate, the muscles surrounding the metatarsal phalangeal joint, and the first metatarsocuneiform joint.

Differing from the other toes, the metatarsophalangeal joint of the great toe contains two plantar sesamoids. The plantar surface of the first metatarsal is grooved to articulate with each sesamoid and is separated by a small ridge of bone (crista) and by a fibrous groove that complements this ridge of the metatarsal head. The dense fibrous plantar pad enshrouds the sesamoids and anchors each to the base of the proximal phalanx. Their medial and lateral margins fix ligaments and muscles (Fig. 2) (Table 1). The proximal aspect receives the flexor hallucis brevis before the sesamoid ligaments attach to the distal end of the first metatarsal. Covered with articular cartilage, the sesamoids protrude minimally through the dorsal surface of the pads, each concave longitudinally and dorsally to fit the plantar articulating surface of the metatarsal head.

The sesamoids usually lay at the same level and were matching in size. The lateral one in four instances lay just proximal to the medial one and in most instances was positioned at just proximal to the medial one. If the sesamoids were small, the flexor hallucis longus passed in the interval between and actually grooved the undersize of the metatarsal head. If the sesamoids were large, the flexor hallucis longus tendon lay in a plantar groove formed by the sesamoids and the intervening fibrous tissue of the plantar pad.

It may well be erroneous to consider the sesamoids as developing in two heads of the flexor hallucis brevis, in that not only does the flexor hallucis brevis insert into the sesamoid, but also some of the fibers of the abductor and the adductor of the great toe plus a strong band of the plantar aponeurosis (Fig. 3). Matzen has regarded the sesamoids as ossifications in the fibrous plantar pads.17

Ligaments of the lateral and medial sesamoids along with the collateral ligaments pass from the epicondyles of the metatarsal head forming a ligamentous complex at the metatarsophalangeal joint (Fig. 4). The lateral ligaments, the more anterior of these two structures, fan out distally and plantarward to anchor into the base of the proximal phalanx. The more proximal bundle, the sesamoid ligament, is equally strong and inserts into the margins of the fibrous plantar pad and the sesamoids. Uniting the collateral and the ligaments of the
sesamoids are the intermediate fibers. The collateral ligaments provide the metatarsophalangeal joint stability. The medial and lateral sesamoid ligaments are charged with the task of holding the sesamoids in their respective grooves.\textsuperscript{9}

**PATHOPHYSIOLOGY OF HALLUS VALGUS**

Hallux valgus is the nosological term for lateral deviation of the great toe with medial displacement of the first metatarsal. The first metatarsophalangeal joint is dislocated or subluxed laterally and usually occurs in conjunction with a bunion, the painful soft tissue swelling over the medial prominence of the metatarsal head (Fig. 5). In addition to the fibularward deviation of the great toe and the varus of the first metatarsal, there is often pronation of the hallux. Once displacement of the great toe occurs, other deforming factors come into play.\textsuperscript{16}

**FIRST METATARSAL - MEDIAL DEVIATION**

As the subluxation of the metatarsophalangeal joint occurs with lateral deviation of the proximal phalanx of
the great toe, the medial migration of the metatarsal head progresses. Medial displacement of the metatarsal head, which occasionally occurs in conjunction with a congenitally wide metatarsal head, is often affected by external pressures, for example, shoe pressure. As the first metatarsal head migrates medially, it can assume a dorsally displaced position as seen occasionally with migration of the fifth metatarsal head in splay foot. The descriptive deformity occurring at the medially displacing metatarsal head is the medial eminence. The medial articular surface of the metatarsal head is exposed to overlying capsule and is subjected to soft tissue and extrinsic pressure, thus causing degenerative changes. The opposing proximal phalangeal base, despite its valgus attitude, undergoes sparse articular cartilage degenerative changes. The so-called “sagittal groove” evolves and is frequently used to determine the level of the ostectomy of the medial eminence (Fig. 6). The groove is occasionally laterally placed, and using this landmark in the manner above may result in excessive removal of the cartilagenous articulation.

The etiology of the sagittal groove has been discussed by several authors. Jordan and Brodsky\(^{13}\) conclude that it might be due to pressure of the margins of the proximal phalanx. Clark\(^{4}\) states that the sagittal groove evolved from the erosion of the articular cartilage and degeneration of the medial aspect of the metatarsal head. Haines and McDougall\(^{10}\) suggest that it was formed by degeneration of the articular cartilage and weakness of the bony trabeculae deep to the groove. This is considered an area of minimal pressure due to lack of stimulation rather than erosion secondary to external pressure. It is well-known by anatomic studies\(^{10}\) that the sagittal groove incorporates the old groove of the medial sesamoid. Similar degenerative changes can be seen on the plantar aspect of the first metatarsal head at the crista. A degenerative state on the medial articular surface of the metatarsal head ensues secondary to loss of congruency with the proximal phalanx and medial sesamoid.

Two theories for the progressive nature of the medial protuberance or medial eminence in hallux valgus are the propounded: One\(^{7}\) is explained by a traction phenomena secondary to the deviation of the great toe. As a result of lateral subluxation of the great toe, the first metatarsal phalangeal joint capsule lies on the medial articular surface of the metatarsal head. The stretch in the medial ligaments causes inflammation of the medial aspect of the metatarsal head; thus, by traction phenomena, this causes a fibrocartilagenous outgrowth that ossifies.\(^{7}\) The other theory\(^{10}\) considers the eminence not to be a new growth but a part of the metatarsal head that was originally articulated with the proximal phalanx. It suggests that the new bone, if it forms, appears on the lateral side in relation to displaced phalanx and sesamoids. The medial prominence is, therefore, part of the normal head which was originally supported proximally by the medial ligaments and the proximal phalanx distally. After displacement of the phalanx, the medial aspect of the metatarsal head articulates with the stretched capsule and ligaments.

**PRONATION OF THE GREAT TOE**

With lateral deviation of the great toe and varus of the first metatarsal head, pronation of the hallux often occurs. This is another deformity generally thought to be due to the medial and dorsal displacement of the metatarsal head. The muscle imbalance between the proximal phalangeal insertion of the abductor hallucis and the adductor hallucis initiates the pronation for it is by virtue of the expansion of their insertions to the sesamoids and to the proximal phalanx that the deformity occurs. As the metatarsal head subluxes from the sesamoid complex, the sesamoids rotate laterally on the metatarsal head in the space between the first and second metatarsal. As this occurs, they also rotate the proximal phalanx and the rest of the great toe into a pronated position. This does not occur all the time, but only when the sesamoids rotate onto the lateral side of the first metatarsal. If they stay straight, only subluxation and hallux valgus occur without pronation. The pull of the extensor hallucis longus and brevis muscles, now from a more lateral vector, forces the proximal phalanx into a dorsal and lateral position. When the metatarsal head subluxes from the sesamoid complex, the abductor head shifts plantarwise and acts largely as a flexor. Occasionally one will see a plantar and laterally deviated hallux. Factors that accentuate a pronation of the great toe are also seen in entities that have a wide arc of

**TABLE 1**

Muscles and Ligaments of the Sesamoid Complex

<table>
<thead>
<tr>
<th>A. Muscles</th>
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<tbody>
<tr>
<td>1. Extensor hallucis longus</td>
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<tr>
<td>2. Extensor hallucis brevis</td>
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<tr>
<td>3. Abductor hallucis</td>
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<tr>
<td>4. Medial head, flexor hallucis brevis</td>
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<td>5. Flexor hallucis longus</td>
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<td>6. Lateral head, flexor hallucis brevis</td>
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<td>7. Adductor hallucis</td>
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<tr>
<th>B. Ligaments</th>
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<tr>
<td>1. Medial sagittal hood</td>
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<tr>
<td>2. Lateral sagittal hood</td>
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<tr>
<td>3. Medial sesamoid</td>
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<tr>
<td>4. Lateral sesamoid</td>
</tr>
<tr>
<td>5. Intersesamoid</td>
</tr>
<tr>
<td>6. Medial collateral</td>
</tr>
<tr>
<td>7. Lateral collateral</td>
</tr>
<tr>
<td>8. Plantar fascia(^*)</td>
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<tr>
<td>9. Transverse metatarsal</td>
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\(^*\) Originates from calcaneus and inserts in part into the sesamoids. 
motion at the subtalar joint such as pes planus, pes valgus, contracted heel cords in association with tight hamstrings, calcaneovalgus foot, and internal tibiofibular torsion. When the hindfoot goes into excessive pronation, the forepart of the foot follows and excessive weightbearing pressures now are resting medially at the first metatarsus complex. A clue to excessive pronation of the great toe is a callosity that forms along the medial border of the interphalangeal joint due to pressure from weightbearing associated with friction.

**LATERAL DISPLACEMENT OF THE SESAMOIDS**

In hallux valgus deformity, the two sesamoids appear to sublux laterally in their relationship to the metatarsophalangeal joint of the great toe. As the metatarsal head migrates medially, the sesamoids actually remain with the proximal phalanx. Thus, the insertions of the tendons of the abductor hallucis and the adductor hallucis, as well as the tenacious plantar fibrous pad, hold the sesamoids in position lateral to the first metatarsal head. Also considered must be the transverse metatarsal ligament that holds the fibrous pad that secures the second metatarsal head (Fig. 7). Abnormal stress and weightbearing are placed upon this area as the structural relationships and direction of muscle force are changed.

The new location of the sesamoids beneath the metatarsal head facilitates erosion and chondromalacia
secondary to incongruity of the metatarsophalangeal joints. The amount of displacement of the fibular or lateral sesamoid may vary from mild subluxation to severe displacement so that the lateral sesamoid will lie almost between the first and second metatarsal heads. The amount of displacement should be demonstrated by tangential X-rays taken prior to anticipation of any surgical procedure, particularly when contemplating excision of the lateral sesamoid (Fig. 8). Postoperative similar areas will document corrected repositioning of the sesamoids, which is so essential to lasting postsurgery results with correction of muscle imbalance.

Thus, the structures involved in the metatarsal head/sesamoids displacement include muscle, ligament, capsule, tendons, and bone. All of these changes and the first metatarsophalangeal joint-sesamoids relationship alter the normal anatomy to varying degrees. With mild hallux valgus the measured deformity is lateral deviation of the great toe. As severity increases, pronation of the great toe and medial subluxation of the metatarsal head from the sesamoid base occur. With the plantar fibrous pad and sesamoids occupying a more lateral position in relationship to the metatarsal head, the medial collateral and medial sesamoid ligaments become stretched. The groove for the lateral sesamoid is normal but the groove for the medial sesamoid becomes eroded and encroaches on the bony ridge (crista) that separates the sesamoid facets (Fig. 9). Eventually, the crista becomes eroded, no longer resistive to the medially subluxing metatarsal head. The ligaments of the lateral sesamoid will shorten, thus preventing replacement of the sesamoids into the original position. As the deformity becomes more severe, the lateral sesamoid will appear to turn on the lateral surface of the metatarsal head. The medial sesamoid will shift to the flattened surface of the crista. It should be noted that the sesamoids move laterally only after destruction of this bony ridge—the crista. Clinically, on anteroposterior
Fig. 6. The sagittal groove. Representation of the sagittal groove which can be quite striking as demonstrated in this intraoperative photograph.

Fig. 7. The transverse metatarsal ligament inserting into the fibrous plantar pad from the sesamoid complex. Photograph of a forefoot gross specimen with the second and third metatarsal heads excised. The transverse metatarsal ligament is seen between the second metatarsal pad and the medial sesamoid at the great toe metatarso-phalangeal joint.

Radiographs, the lateral sesamoid is exposed lying lateral to the metatarsal head, protruding into the first intermetatarsal space. With a shoe on, the first metatarsal is supported medially and is not displaced as far into varus. In the more severely affected cases, the sesamoids are larger than normal. Criteria for success in bunion surgery were recognized in the 1920s as based upon replacement of the sesamoids to their original positions.

POSITION OF THE TENDONS

As lateral displacement of the great toe progresses, tendinous deformities and forces come into play and the so-called bowstring effect of the plantar-displaced abductor hallucis occurs. The dorsal extensor aponeurosis of the extensor hallucis longus attenuates losing its centralization and migrates laterally with loosening and attenuation of the medial capsular structures (Fig. 9). As a result, the extensor hallucis longus and even the extensor hallucis brevis bowstring laterally relative to the medially displaced first metatarsal head. The flexor hallucis longus, along with the sesamoids and the tendons that insert into them, also pull from a more lateral position with respect to the first metatarsophalangeal joint. The great toe not only is pulled into valgus but also can be seen to pronate. As months and years elapse, the tendons contract, making it occasionally difficult to gain correction at surgery without tendon lengthening. In rheumatoid arthritis due to their severe deformity over a prolonged period of time, one must expect extensor hallucis longus and/or brevis to be
contracted and tendon lengthening procedures are often necessary.

In the hallux valgus, the flexor hallucis longus and extensor hallucis brevis are displaced so that, in addition to their main function of flexion-extension, they also adduct the great toe toward the second toe. Thus, the ligament of the medial sesamoid stretches and the first metatarsophalangeal joint assumes a more tibial position in relation to the rest of the foot and the adductive forces become greater. The extensor hood's medial attachment to the sesamoid complex becomes attenuated displacing the extensor aponeurosis laterally (Fig. 9). The abductor hallucis moves to a plantar relationship as the metatarsal head displaces medially losing all power to abduct. The flexor hallucis longus embedded plantarly and between the two sesamoids is now effectively lateral to the varus displacing metatarsophalangeal joint providing a valgus force to the great toe. The two heads of the flexor hallucis brevis and adductor also assume this same relationship adding to the valgus deforming forces.

**BINDING MECHANISM OF THE METATARSAL HEADS**

The binding mechanism of the metatarsal heads cannot be discussed without mention of the extensor hallucis longus, the medial brevis fibers, or the medial sagittal hood ligament (Fig. 10). These latter oblong-shaped fibers attach the extensor hallucis longus and brevis to the plantar fibrous bed, proximal phalanx, periosteum, and fibrous tunnel of the flexor hallucis longus. On the dorsum of the proximal phalanx, the medial hood fibers blend in and cover the insertion of the extensor hallucis brevis. Medially, they pass deep to the conjoined tendon (abductor hallucis and medial head of the flexor hallucis brevis) and the plantar apo-
neurosis to insert into the proximal phalanx. All of the above-mentioned structures lie and blend medial to the metatarsophalangeal joint and attach to the proximal phalanx and not to the metatarsal. When the great toe is adducted, it carries with it all of these medial attachments and exposes the medial metatarsal articular surface. The collateral ligaments and sesamoid ligaments are the only structures that tie into the metatarsal.

Lapidus and McMurray popularized the theory that when the metatarsals are spread, the transverse ligaments are stretched; but the truth is quite the contrary, as Haines and McDougall have demonstrated. As the first metatarsal head moves medially, the deep transverse metatarsal ligament remains intact as does the fibrous plantar pad with its sesamoids. It should be stressed, as demonstrated by Acton, that the transverse metatarsal ligament is not attached to the meta-
tarsals but to the fibrous pads of the metatarsal heads. What fails is the ligament of the medial sesamoid. Thus, on roentgenographic evaluation, the sesamoids look as if they are moving laterally when, in fact, they remain embedded in the fibrous pad and are held snugly in place laterally by the transverse metatarsal ligament. The same type of failure may occur at the fifth metatarsal head (the lateral ligament of the fifth metatarsal pad) and may explain in part the pathology of the splay foot.

**VARUS OF THE FIRST METATARSAL**

Metatarsus primus varus most often is associated with hallux valgus. The hallux of the human embryo has simian features that are lost with growth. The varus of the first metatarsal, as measured by the angle of the long axis of the first metatarsal and second metatarsal, is marked in the fetus at 8 weeks (32 degrees), but decreases to become 6 to 10 degrees in the normal adult foot. Varus deviation can be associated with obliquity of the articular surface of the metatarsal (Fig. 11) as one might see with Blount’s disease of the tibia. The normal cuneiform-first metatarsal joint is set transversely and occasionally obliquely without metatarsus primus varus or hallux valgus (Fig. 11).

Metatarsus primus varus with a short first metatarsal may predispose to lateral deviation of the great toe. This may also be a congenital variant as seen in association with adolescent hallux valgus. The so-called Morton’s syndrome with a short, hypermobile first metatarsal can be associated with hallux valgus. If one chooses a base of the first metatarsal osteotomy to correct hallux valgus, he or she may want to take into consideration that a short metatarsal may be lengthened by an opening wedge and grafting on the tibial side, and the rare longer metatarsal may be shortened by a closing wedge based laterally without grafting.

**DISCUSSION**

To consider the sesamoids as solely attached to the medial and lateral head of the flexor hallucis brevis may well be erroneous. The abductor hallucis and adductor hallucis also insert into the sesamoids as well as the extensor hallucis and extensor hallucis brevis, the latter via their sagittal hood ligaments. Including the flexor hallucis longus as it travels through the groove of the sesamoids, the entire sesamoid complex consists of seven muscles and tendons, eight ligaments, and two sesamoid bones as shown. The eight ligaments anchoring into the sesamoid complex are medial sagittal hood, lateral sagittal hood, medial sesamoid, lateral...
CONCLUSIONS

1. Conventional techniques of bunion surgery and what they should accomplish should be assessed.
2. There are seven tendons that cross or are involved with the function of the great toe metatarsophalangeal joint: extensor hallucis longus, extensor hallucis brevis, adductor hallucis, fibular head of flexor hallucis brevis, flexor hallucis longus, tibial head of flexor hallucis brevis, and abductor hallucis.
3. In addition to the influence of the above-mentioned seven tendons, seven ligaments anchor into the sesamoids: medial sesamoid ligament, lateral sesamoid ligament, intersesamoid ligament, plantar fascia, medial sagittal hood ligament, transverse metatarsal ligament, and lateral sagittal hood ligament.
4. The crista is important as a deterrent to splaying of the first metatarsal head.
5. The contracture of the lateral sesamoid ligament is important.
6. The attenuation of the medial sesamoid ligament is equally as important as the attenuation of the medial collateral ligament when the first metatarsal swings into varus and the great toe drifts into valgus.
7. The sesamoids do not dislocate; the first metatarsal deviates into varus escaping the grip of the sesamoid complex.

PROPOSAL

A proposed solution to the varus displacement of the first metatarsal head and relaxation of the medial sesamoid ligament would be to not only reduce the intermetatarsal splaying via osteotomy but also to release the lateral sesamoid ligament combined with pllication of the medial sesamoid ligament and medial collateral ligament.12

SUMMARY

Pathoanatomy of the hallux valgus deformity involves many structures that make the term “simple bunion” a gross understatement. The essential pathology is not dependent on one structure but on many. The crista, ligament of the medial sesamoid, medial hood ligament of the extensor hallucis longus and brevis, obliquity of the medial cuneiform-first metatarsal joint, and increasing valgus pull of those muscles that insert not only into the sesamoids but also into the base of the proximal phalanx all combine to produce the hallux valgus. The medial eminence is probably a combination of pre-existing bone as well as reactive exostosis. The probable creation of the sagittal groove has been discussed. Only when these pathoanatomic developments are understood can the “bunion surgeon” anticipate satisfactory results from his surgery.

REFERENCES


British Orthopaedic Foot Surgery Society

The 1984 meeting of the British Orthopaedic Foot Surgery Society will be held on November 29 and 30 in Bath, Somerset. Anyone interested in presenting a paper should contact Leslie Klenerman, Ch.M., F.R.C.S., by September 30, at the following address: Northwick Park Hospital and Clinical Research Centre, Watford Rd., Harrow, Middlesex, HA1 3UJ, England.