Is the Radiographic Appearance of the Hallucal Tarsometatarsal Joint Representative of Its True Anatomical Structure?

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The medial cuneiforms and first metatarsals were identified in 515 randomly selected specimens at the Hamman-Todd osteology collection in the Cleveland Museum of Natural History in Cleveland, Ohio, and the transverse plane angulation of the hallucal tarsometatarsal joint was determined by direct measurement of the selected bones. Medial cuneiforms were subsequently separated into three categories corresponding to the amount of measured obliquity. The first tarsometatarsal joint was reassembled, and the paired medial cuneiforms and first metatarsals were radiographed at different declination angles in inverted, everted, and rectus positions. Radiographic evaluation revealed discordance between the appearance of atavism and true atavism in the cuneiform. Specifically, it was determined that the position of the hallucal tarsometatarsal joint significantly influenced the appearance of atavism in the cuneiform. It is concluded that the position of the first ray in an anteroposterior radiograph can produce the appearance of an increased obliquity angle of the medial cuneiform, resulting in an inaccurate representation of the hallucal tarsometatarsal joint. (J Am Podiatr Med Assoc 92(9): 491-498, 2002)

Many authors have identified the hallucal tarsometatarsal joint as the apex of deformity in cases of metatarsus primus adductus leading to hallux abducto valgus.1-13 Some have attributed the deformity to developmental arrest of growth in the medial aspect of the first cuneiform, resulting in increased obliquity.14 Others believe that intrauterine position is to blame for malformation of the medial cuneiform resulting in increased obliquity.14, 15 Both hypotheses are popular for explaining why metatarsus primus adductus is present in most cases of juvenile hallux abducto valgus deformity.7, 16

The hallucal tarsometatarsal joint has also been viewed as the apex of deformity in adults with hallux abducto valgus and metatarsus primus adductus.9, 11, 16 It has been suggested that medial cuneiforms with an increased obliquity angle are phylogenic remnants of our quadrupedal and more arboreal ancestors.17-23 A hypermobile first ray with a more opposable hallux was a definite advantage for our close mammalian cousins.19, 21, 24 However, our bipedal gait demands a...
rigid lever for propulsion.\textsuperscript{17, 19-23} When the foot abnormally pronates during closed-kinetic-chain gait, the result is an inefficient gait cycle and a painful deformity.\textsuperscript{25}

Others believe that purely biomechanical faults during closed-kinetic-chain gait cause bony and soft-tissue changes that result in structural adaptation over time. Thus an increased obliquity of the medial cuneiform would be a result of Wolf and Davis laws leading to structural deformity.\textsuperscript{5, 15, 26} This process is due to abnormal pronation in the gait cycle, resulting in a hypermobile first ray.\textsuperscript{4, 10, 25}

Many surgical procedures have been developed to address the medial cuneiform in these situations. Some have advocated fusion of the hallucal tarsometatarsal joint.\textsuperscript{1, 2, 11} Others have performed lateral wedge resection or medial bone graft wedge insertion to address the obliquity of the medial cuneiform.\textsuperscript{5-7, 13} The modified Lapidus procedure may be the most popular surgical method of addressing the hallucal tarsometatarsal joint as the apex of the deformity.\textsuperscript{4, 9, 11, 13, 27}

Preoperative planning is generally done with the aid of the patient’s radiographs. Standard weight-bearing anteroposterior radiographs with the tube head angled at 15\textdegree\ and the cathode ray tube centered at the navicular are used to determine whether the medial cuneiform has excessive obliquity contributing to the deformity. It has been suggested that the radiographic appearance of the foot can change depending on whether the foot is in a supinated or pronated attitude.\textsuperscript{9, 28} In particular, the first ray has been shown to invert or evert with pronation or supination of the foot.\textsuperscript{7, 29-31} The change in first metatarsal declination angle can also result in differences in overlap and projection of midfoot bones.\textsuperscript{32} The authors suggest that the position of the first ray on anteroposterior radiographs can result in the appearance of increased medial cuneiform obliquity or atavism, resulting in an inaccurate radiographic representation of the hallucal tarsometatarsal joint.

**Materials and Methods**

A total of 515 feet were randomly selected from human specimens at the Hamman-Todd osteology collection in the Cleveland Museum of Natural History in Cleveland, Ohio. These specimens represent people of varying race, sex, and origin. The angulation of the distal facet of the medial cuneiform was measured with a tractograph, with one arm placed along the lateral surface and the other arm rotated until it was along the facet itself (Fig. 1). The values obtained were recorded as a deviation from 90\textdegree\ in the transverse plane and were considered to be the anatomical obliquity angles of the medial cuneiform in the study.

A simple statistical analysis was performed to determine the mean, median, mode, range, and standard deviation (SD) of the 515 cuneiforms measured. The specimens were then divided into three groups: cuneiforms with measured obliquity angles within 1 SD of the mean value, below 1 SD, and above 1 SD. For the purpose of this study, the specimens with measured anatomical obliquity angles within 1 SD were considered the normal range group; above 1 SD were the high outliers; and below 1 SD were the low outliers.

One specimen was randomly selected from each of the three groups, and the hallucal tarsometatarsal joints were reassembled using Sculpey III (Polyform Products, Elk Grove Village, Illinois), which is kiln-safe pottery-repair putty (Fig. 2). Sculpey III was chosen because of its relative radiolucency and consistency compared with other puttylike substances. The cuneiforms were tagged with various shapes of steel piano wire to maintain orientation of topographic structure when viewing the radiographs. A straight piece of wire was fixed to the dorsal ridge and wire in the shape of a circle was attached to the site of insertion of the anterior tibial tendon on the medial side (Fig. 3). Wire in the shape of a triangle was placed on the lateral side, and the plantar aspect of the distal facet was traced with wire in a half-circle (Figs. 4 and 5).

All three specimens were then radiographed in a baggage-type x-ray unit (Faxitron Cabinet X-ray System, model 43855A, Hewlett-Packard, Palo Alto, California) at 115 kV(p) for 24 sec using standard screened...
film in “ready packs.” Ready packs are radiographic film within light, tight paper envelopes used without intensifying screens. Radiographs were obtained with the reassembled hallucal tarsometatarsal joints in inverted, everted, and rectus positions at declination angles of $0^\circ$, $10^\circ$, $20^\circ$, and $30^\circ$ (Fig. 2).

The radiographic obliquity angle was recorded by drawing a line along the lateral side of the medial cuneiform and along the distal facet of the medial cuneiform. The obliquity value was then determined by calculating the angle’s deviation from $90^\circ$ in a similar fashion as the anatomical measurement was obtained. The authors determined that measuring the obliquity from the lateral aspect of the medial cuneiforms was the most consistent method, as the lateral aspect is more planar owing to its articulation with the intermediate cuneiform. Also, the medial aspect of the medial cuneiform tends to be quite variable in shape, size, and prominence.

Results

The average measured anatomical obliquity angle was $15.10^\circ$, with an SD of $5.94^\circ$, a median value of
When the reassembled first tarsometatarsal joints were radiographed perpendicular to the film in a rectus position, the obliquity angles closely matched the values obtained anatomically. However, the medial cuneiform clearly changes shape and appearance with inversion and eversion, becoming less rectangular and more trapezoidal on radiographs.

Figures 7 through 9 show radiographs of three reassembled hallucal tarsometatarsal joints (all lefts). The first ray on the left is a specimen randomly selected from the group of medial cuneiforms considered to be high outliers. The first ray in the middle is a specimen randomly selected from the population considered to be within the normal range of measured medial obliquity. The first ray on the right is a specimen randomly selected from the group with medial obliquity values considered to be low outliers. The actual measured obliquity of the three specimens, from left to right, was 24°, 15°, and 6°, respectively. All medial cuneiforms were tagged with steel piano wire as mentioned previously.

Figure 6. Frequency of measured obliquity angles.

As the first ray declination angle increases, there appears to be an increase in the obliquity angle. Moreover, finding points from which to draw lines to measure the obliquity angle becomes difficult owing to the increase in overlap of the joint (Fig. 7). The dorsal ridge of the medial cuneiform results in the appearance of atavism owing to its projection over the hallucal tarsometatarsal joint. This is further complicated with inversion and eversion, which cause increased projection of the plantar aspect of the medial cuneiform and an even more skewed view of this joint. This atavistic appearance increases as the first ray declination angle increases, especially with the first ray in an inverted position (Fig. 8). Eversion of the first ray changes the appearance of the hallucal tarsometatarsal joint owing to lateral projection of the plantar aspect and medial projection of the dorsal ridge (Fig. 9).

Discussion

First ray inversion is due to ground reaction forces in a hypermobile foot where the peroneus longus muscle cannot stabilize the first ray against the ground.29, 32 Ironically, many authors have described an increased hallucal tarsometatarsal angulation coexisting with the hypermobile foot type leading to instability of the first ray.1, 2, 8-11, 26, 33

Currently, there are many accepted measurements for radiographic and clinical observations. These measurements are an attempt to establish the presence or severity of a given deformity.26, 34, 35 Many of these measurements are very subjective and include variables that are ignored, not yet understood, or not generally accepted. This study addresses the concept of an atavistic medial cuneiform. It is generally accepted that an atavistic medial cuneiform is instrumental in the development of hallux abducto valgus and metatarsus primus adductus deformity.1, 2, 7, 8, 11, 17

The findings of this study indicate that the appearance of atavism results from both angulation and motion of the first metatarsal and medial cuneiform as a unit. The hallucal tarsometatarsal joint is often considered the apex of the deformity in cases of metatarsus primus adductus in conjunction with hallux abducto valgus. The data presented earlier suggest that radiographic evaluation of the hallucal tarsometatarsal joint is greatly influenced by foot position, tube head angulation, and first metatarsal declination angle. The authors suggest that the position of the first ray as projected on anteroposterior radiographs can result in the appearance of increased medial cuneiform obliquity. This gives the appearance of atavism, resulting in an inaccurate radiographic representation of the hallucal tarsometatarsal joint. This may cause misinterpretation of the true apex of a deformity; thus any correction that might be attempted would be directed at a deforming factor that is not actually present.

Conclusion

The data presented here indicate that the radiographic appearance of the hallucal tarsometatarsal joint is not representative of its true anatomical structure. Analysis of the data shows the average obliquity of the distal articular facet of the medial cuneiform to be 15.10°. Radiographic analysis demonstrates that the projection and magnification of the dorsal ridge of the medial cuneiform can give the appearance of
atavism. This was most obvious as the first ray declination angle was increased, particularly when the first ray was in an inverted position.

This study does not dispute the idea that increased medial obliquity of the first cuneiform can be a deforming factor in metatarsus primus adductus. In fact, very high obliquity angles were recorded for some specimens. However, radiographic views of the hallucal tarsometatarsal joint can be deceptive. Even when anteroposterior radiographs are taken with the subtalar joint in neutral, a varus or valgus position of the midtarsal joint can cause first ray eversion or inversion. Perhaps the best method of eliminating overlap of the hallucal tarsometatarsal joint is to obtain a lateral radiograph of the foot in subtalar joint neutral. The next step is to measure the first metatarsal declination angle and obtain an anteroposterior radiograph of the same foot with the tube head angled at a value equal to the first metatarsal declination angle.

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References

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Figure 8. A, The three specimens are in an inverted position with 0° declination. The inverted position alone can create the appearance of atavism owing to the projection of the dorsal ridge of the medial cuneiform laterally and the projection of the plantar aspect of the medial cuneiform medially. B, The three specimens are in an inverted position with 10° declination. The increased declination causes lateral and distal projection of the dorsal ridge of the medial cuneiform, emphasizing the appearance of atavism. C, The three specimens are in an inverted position with 20° declination. The increased declination further skews the appearance of the hallucal tarsometatarsal joint. D, The three specimens are in an inverted position with 30° declination. The increased declination further skews the appearance of the hallucal tarsometatarsal joint.


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**Figure 9.** A, The three specimens are in an everted position with 0° declination. Lateral projection of the plantar aspect and medial projection of the dorsal ridge of the medial cuneiform are observed. B, The three specimens are in an everted position with 10° declination. The increased declination further skews the appearance of the hallucal tarsometatarsal joint. C, The three specimens are in an everted position with 20° declination. The increased declination further skews the appearance of the hallucal tarsometatarsal joint. D, The three specimens are in an everted position with 30° declination. The increased declination further skews the appearance of the hallucal tarsometatarsal joint.