Position of the first metatarsophalangeal joint and the effect on hallux abductovalgus deformity progression and reversal

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There has not been any literature describing changes in intermetatarsal (IM) angle 1,2 of the foot related to position of the first metatarsophalangeal joint (MTPJ). This study looks at the effect on the IM angle with loading of the foot and attempted dorsiflexion of the 1st MTPJ in 14 consecutive feet with bunion deformity. We also examine the effect of maximal dorsiflexion of the first MTPJ on the IM angle 1,2. This is a radiographic study. The pathogenesis of hallux abductovalgus is a subject of much discussion. Conclusive evidence has not been obtained as to the etiology of this common condition, and many theories have been advanced. This study shows that there is an effect on the IM angle under different angular conditions of the first MTPJ. The author concludes that there is a significant decrease in the IM angle between mets 1,2 with dorsiflexion of the first MTPJ and a change of the deformity with dorsiflexion attempted with weight bearing (WB) in all subjects. It is suggested that restoration of motion of the first MTPJ decreases the deformity. This leads the author to believe that conservative care and restoration of motion of the first MTPJ may reduce the deformity of hallux abductovalgus as assessed by IM angle 1,2.

Keywords: functional hallux limitus, etiology of hallux abductovalgus

This study proposes the etiology of hallux abductovalgus (HAV) to be primarily a WB limitation of dorsiflexion of the hallux and resulting lack of plantarflexion of the first metatarsal in closed kinetic chain as a primary etiology of HAV deformity. This is a radiographic study. The study was done to see if improving dorsiflexion of the first metatarsophalangeal joint (MTPJ) would have any effect on the actual deformity of varus (adduction) deformity of the first metatarsal radiographically, and whether attempted dorsiflexion with WB, would tend to make the deformity worse. A bunion has been described as a static deformity [1]. Others have shown that dynamic flexion of the Hallux increases the medial deviation of the first metatarsal and lateral deviation of the Hallux. This is proposed to be the result of lateral deviation of the flexor tendon beneath the first MTPJ after development of the HAV deformity [2,3].

There is no literature on dynamic changes in IM angle 1,2 with different positions of the first MTPJ, to the authors knowledge.

Review of the literature regarding the etiology of HAV deformity has shown the following findings. The pathogenesis of HAV deformity has been a topic of much debate and numerous studies have shown that there has been a poor correlation to any one cause [4,5]. Proposed causes can be divided into three groups; shoe gear, anatomy of the first ray, and biomechanical abnormalities. Shoe gear generally has shown a poor correlation to HAV deformity. If shoes were the causative factor, then all people wearing poor shoes would develop the deformity. This is clearly not the case. Studies have shown the same degree of deformity in shoe and non-shoe wearing populations [6,7]. However, others show a higher incidence of the deformity in shoe wearing populations, perhaps suggesting a contributing role [8].
Anatomical variations may create instability of the first ray and predispose an individual to HAV deformity. The first metatarsocuneiform joint (MCJ) has about 41% of the available motion of the medial column of the foot [9]. Faber, et al., showed 57% of sagittal plane motion occurred at the First MCJ, and 82% of transverse plane motion occurred at the first MCJ [10]. A smooth MCJ surface with one articular facet has been found to be highly correlated with HAV deformity [11]. More than one articular facet seems to impart more stability and is less commonly associated with the deformity. An articular facet between the first and second metatarsal base has been highly correlated with HAV deformity [12]. A smooth, rounded, and narrower first metatarsal head has been found more likely associated with HAV deformity [13,14]. A longer first metatarsal relative to the second metatarsal is correlated with HAV deformity [3,14]. There is an eversion torsion of the first metatarsal in those presenting with HAV deformity compared to controls [15]. Inversion of the metatarsal does result in increased stiffness of the first ray [15]. A flatter foot has not been more commonly associated with HAV deformity [11,15]. Pronation of the Subtalar joint has been implicated with HAV deformity [16]. Others dispute this finding [17,18].

Patients and Methods

All consecutive patients used for this study had symptomatic HAV deformities. All patients had a positive functional hallux limitus test, as described in this article [19]. The patients consented to the study. They were excluded from the study if they had previous foot surgery or presented with degenerative or inflammatory arthritis. Additional exclusion criteria included diabetes Mellitus or neurologic disease. They had at least enough motion available at the first MTP] to allow for the normal plantarflexion of the first metatarsal to occur through the windlass mechanism. AP weight bearing radiographs were obtained of patients with HAV deformity in angle and base of gait. Tube angle of 15 degrees cephalad to maintain the tube parallel to the foot structure, was maintained in all radiographs (Figure 1). A second radiograph was obtained while attempting to dorsiflex the hallux while maintaining full WB (Figure 2).

The hallux was not manipulated either medially or laterally during the dorsiflexion procedure. Significant resistance to dorsiflexion was present in all feet. Enough force was applied so that there was not any additional dorsiflexion of the joint available. The only motion available clinically was gliding motion of the first MTP]; plantarflexion of the first metatarsal could not be obtained. Without leaving the room or changing body position, a third radiograph was obtained with the hallux dorsiflexed (Figure 3). To accomplish this, the test subjects were asked to roll back on their heels so that dorsiflexion could be obtained, then roll forward for full WB on the forefoot. The IM angle was measured on all three radiographs and compared by bisecting metatarsals one and two visually, and measuring the angle between the two bisections. Each subject served as their own control.
Figure 3 Radiograph obtained in the same angle and base of gait with Hallux fully dorsiflexed. In order to achieve this, the patient rolled back on the heel and then the hallux was dorsiflexed to end range. Then, they rolled back on the forefoot in a relaxed stance. The purpose of this is to determine if the IM angle changed with dorsiflexion of the hallux. Note the significant reduction in the IM angle compared to Figure 1 and Figure 2.

Results

The data was analyzed in terms of disruptive statistics (Table 1, Figure 4), and tests of the null hypothesis were used to compare the IMA's on the three different views of each subject's feet. Statistical significance was defined at the 5% (p less than or equal to .005) level.

<table>
<thead>
<tr>
<th>Age</th>
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<th>IMA2</th>
<th>IMA3</th>
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<td>9</td>
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Table 1 Results. Age; Mean 50.54 ± sd 13.34 (median 51, minimum 12, max 66). IMA1; Standard WB images of the foot. Mean 11.69 ± 2.98 Median 12 Min 5 Max 15. IMA2; WB images with attempted dorsiflexion of the hallux; Mean 12 ± 4.18, Median 13, Min 5, Max 18. IMA3; WB radiographs with the hallux maximally dorsiflexed; Mean 8.69 ± 3.5, Median 8, Min 4, Max 14.

Figure 4 Comparison of IM angle1,2; blue is standard WB; red with attempted dorsiflexion; green is fully dorsiflexed.

<table>
<thead>
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<th>IM Angle</th>
<th>Probability</th>
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<td>IMA1 to IMA2</td>
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<tr>
<td>IMA2 to IMA3</td>
<td>.0016</td>
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Table 2 Wilcoxon signed rank test results.

Sign rank test to test the null hypothesis between IMA1 and IMA2 and IMA1 and IMA2 and IMA 2 and IMA3 was used through the nonparametric Wilcoxon signed rank test.

IMA 1 to IMA 2 the probability is .4113, which was not clinically significant. IMA 1 to IMA 3 probability was .0013, which is highly statistically significant. IMA 2 to IMA 3 probability was .0016, and highly statistically significant (Table 2).

There was an increase in the IMA between metatarsals 1,2 with dorsiflexion force applied to the first MTPJ as measured by both the mean and median observations. The value of .4113 was not statistically significant, however, there was an observed IMA increase with dorsiflexion stress in all but 4 feet. It is statistically significant that the IMA (comparing both the WB and WB with attempted dorsiflexion radiographs to radiographs obtained with maximal hallux dorsiflexion) decreased significantly.
Discussion

It appears from these results that the IM angle 1,2 is dynamic and changes depending on the position of the first MTPJ. Reduction of this angle with maximal hallux dorsiflexion is exciting and may suggest that if hallux dorsiflexion is allowed to occur, there will be a reduction of the HAV deformity. For technical reasons the hallux valgus angle could not be assessed radiographically. It was observed, however, that as the hallux was dorsiflexed, the valgus rotation of the hallux reduced, as well as the hallux abduction in all patients. These findings clearly show a major effect on HAV deformity just by bringing the foot into the closed-packed (stable) position through hallux dorsiflexion.

The study did not show a statistically significant increase in the IM angle when dorsiflexion was attempted during WB. One of the observations made is that the metatarsal appeared visually to protrude more medially when dorsiflexion was attempted with WB. It could be that the changes that occur as a result of these deforming forces are gradual and do not show immediately on radiograph. Although not supported by this study, but none-the-less observed in many of the patients, there may be consequences of functioning with an open-packed (loosely organized) position of the foot structure in propulsion.

There appear to be a number of anatomical features including length of the first metatarsal, shape of the articular surface of the first metatarsal, and the facet of the first MCF, that cause less stability of the first ray against deforming forces. It may be that shoes cause some restricted mobility of the first MTPJ, and may likely explain their potential contribution as a causative factor of this condition [20]. Pronation of the rearfoot can also cause an elevation of the first ray and subsequent restricted ROM of the first MTPJ. This dorsal displacing force has been shown to restrict ROM of the first MTPJ [21]. This restriction of motion will have the effect of allowing the foot to be in the open packed position in propulsion. A long first metatarsal will cause increased compression forces in the first MTPJ, and relative elevation of the first metatarsal.

Figure 5 Rotation around the more vertical axis of the first ray will result in more transverse plane rotation of the first metatarsal (hallux abductovalgus) and rotation around the lower pitched axis will result in more sagittal plane motion of the first metatarsal (hallux limitus or rigidus).

The direction of the axis of the first ray will determine the overall direction the first metatarsal will move when the foot is in the open packed position in propulsion. As the axis is lower the motion will be in the transverse plane and as the axis is more vertical the motion will be more in the sagittal plane. This will determine whether an HAV deformity will develop or whether there will be a Hallux Rigidus deformity (Figure 5).

While there is often very good motion of the first MTPJ in open kinetic chain, the joint ROM may be restricted to only gliding motion without concomitant plantarflexion of the first metatarsal with WB. Hypermobility of the first ray seems to be a misnomer in that these feet typically demonstrate a propensity for elevation of the first ray but a distinct lack of plantarflexion of the first metatarsal in gait. This motion is necessary for the foot to stabilize in the closed packed position described by Hicks [22].
In this situation the compression forces in the first MTPJ can become quite large as the proximal phalanx jams into the metatarsal head as the joint attempts to dorsiflex (Figure 6) [22]. This force needs to be mitigated in some way when motion of the joint is restricted. It is proposed that a lack of motion at the first MTPJ will result in deforming forces at the first MTPJ and first MCJ and cause an increase in the protrusion of the first metatarsal head medially as seen clinically in many of the subjects, however, the findings were unable to show an IM angle increase with attempted dorsiflexion.

The resultant instability of the first MCJ may allow the peroneus longus to apply an eversion force to the first metatarsal, instead of stabilizing the joint, if the first MCJ cannot move into a closed-packed position in propulsion (Figure 7). The antagonistic muscles to the peroneus longus, the anterior tibial and extensor hallucis longus may not be able to counter the effect of the peroneus longus if the closed packed position of the first MCJ is not achievable. This can then result in deviation of the proximal phalanx into valgus. This presents then as a tri-plane HAV deformity.

Tests of hypermobility of the first ray cannot be conducted NWB as they miss the functional significance of motion of the first ray. What is available with WB may differ from what can be observed in OKC. It is the ability of the first ray to plantar flex that is of functional significance, in that this is coupled with dorsiflexion of the hallux. Lesser metatarsal overload is a common comorbidity of the HAV condition [11].

Figure 6  Restriction of motion is present as the first metatarsal is unable to plantar flex to allow normal dorsiflexion to occur to the first MTPJ.

Figure 7  Note that the pull of the Peroneus Longus will evert the entire first ray. It is hypothesized that this may happen with an open packed position of the foot structure.

Considering the tripod of stability of the foot to be the first metatarsal head, fifth metatarsal head, and the center of the heel (Figure 8). The metatarsus primus varus or increase in the IM angle, may in fact be a natural adaptation of the foot to increase the width of the forefoot in an unsuccessful attempt to stabilize an unstable foot structure.

This study postulated that the first MTPJ motion has an impact on bunion development and correction. It was shown that end range dorsiflexion of the first MTPJ will reduce the deformity in all cases. Motion of the first MTPJ is the only way the foot can move into its closed packed position to prevent deforming forces at the first MCJ. This may be partially addressed with footwear allowing more room for the hallux to function [20,23]. Custom orthoses may improve restricted mobility of the first MTPJ in propulsion [24]. However, others have shown that orthoses have caused restriction of motion of the first MTPJ [25-30]. Certain features of an orthosis may be worth considering if an orthosis is to be beneficial. When the medial forefoot is supported in an elevated position (a varus wedge), it has demonstrated worsening of this condition over time [31]. This makes intuitive sense as you are restricting plantarflexion of the first metatarsal, and therefore motion of the first MTPJ when putting an elevation under the first metatarsal head. This has been described [21].
valgus deformity reduced although this could not be tested radiographically in this study. The author suggests that dorsiflexion of the first MTPJ will reduce the HAV deformity and that allowing this motion to occur without impediment may assist in preventing the development of the HAV deformity in susceptible individuals.

Long term prospective studies to look at potential prevention of HAV would be of great interest, and have significant epidemiological implications. Potential reduction of existing deformity by conservative means is exciting.

While this study is limited in size and scope, it is hoped that larger studies will be conducted to look at this issue, and also consider the subjective findings associated with a reduction of the IM angle between metatarsals 1 and 2.

**Limitations**

There are several limitations to this study. The radiographic tube angle in this study was kept steady on all 3 views of the foot. As the foot was brought into the closed packed position this would result in an increase in the metatarsal declination angle, as the first metatarsal plantarflexes. This variable was not controlled in this study.

During the radiographs the plate was changed for each radiograph, this could have allowed the patient to reposition the foot slightly on the plate, although the patient was instructed not to move their body with the plate changes as much as possible. The examiner measured the angles on all radiographs. The radiographs were not read by a third party.

**References**


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**Figure 8** The base of support of the foot has become more narrow as the first metatarsal is not able to accept normal WB because of lack of big toe motion.

This author has utilized a lift under the Hallux to overcome Functional Hallux Limitus of the first MTPJ, a condition that seems to correlate with development of the Bunion deformity. This can be utilized either with or without the use of an orthosis in the shoe [19].

**Conclusion**

This study shows that the IM angle 1,2 is dynamic and reduces with maximal hallux dorsiflexion. Worsening of the deformity when attempting dorsiflexion in WB did not have statistical significance. Although it was observed that in many patients there was a worsening of the deformity with attempted dorsiflexion with WB. It was also observed that as the hallux was dorsiflexed the hallux