

Lateral Sesamoid Position Relative to the Second Metatarsal in Feet with and without Hallux Valgus*

Posição do sesamoide lateral em relação ao segundo metatarso em pés com e sem hálux valgo

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Rev Bras Ortop 2019;54:165–170.

Abstract

Objective To determine if the sesamoids migrate laterally in the feet with hallux valgus or if they only appear to move, maintaining their relationship with the other forefoot structures.

Methods Anteroposterior radiographs of 80 patients (94 feet, all weight-bearing), from the period between 2015 and 2016, were evaluated. Forty-eight had a valgus hallux angle greater than 15° (hallux valgus group) and 46 presented a hallux valgus angle lower than 15° (control group). The distances from the first metatarsus head and the lateral sesamoid bone to the second metatarsus axis were measured. Subsequently, the coefficients of these distances were determined by the length of the second metatarsus to adjust it for different foot sizes.

Results Both the absolute and the relative measures from the first metatarsus head to the second metatarsus axis were significantly different between the groups, with a positive correlation with hallux valgus and intermetatarsal angles. However, neither the absolute nor the relative distance of the lateral sesamoid bone to the second metatarsus was different between the groups, as they did not correlate with hallux valgus or intermetatarsal angles.

Conclusion Despite the medial deviation of the first metatarsus in hallux valgus, the sesamoid bone maintains its relationship with the second metatarsus in the transverse plane. This apparent lateral displacement may lead to misinterpretation of these radiographs. This fact is of paramount importance in the pre-, intra-, and postoperative period of patients with hallux valgus.

Keywords

- hallux valgus
- metatarsal bones
- radiography
- statistical analysis

* Work developed at Serviço de Cirurgia do Pé e Tornozelo, Hospital Universitário Clementino Fraga Filho (HUCFF), Universidade Federal do Rio de Janeiro, Rio de Janeiro, RJ, Brazil.

Resumo

Objetivo Determinar se os sesamoides migram lateralmente nos pés com hálux valgo ou se apenas aparentam deslocar-se, mantendo sua relação com as demais estruturas do antepé.

Métodos Foram avaliadas radiografias na incidência anteroposterior com carga dos pés de 80 pacientes (94 pés) entre o período de 2015 e 2016. Dessas, 48 tinham ângulo de hálux valgo maior do que 15° (grupo hálux valgo) e 46 tinham ângulo de hálux valgo menor do que 15° (grupo controle). Foram medidas as distâncias da cabeça do primeiro metatarso e do sesamoide lateral ao eixo do segundo metatarso. Posteriormente, foram medidos os coeficientes dessas distâncias pelo comprimento do segundo metatarso, a fim de se ajustarem aos diferentes tamanhos de pés.

Resultados Tanto a medida absoluta quanto a medida relativa da cabeça do primeiro metatarso ao segundo metatarso foram significativamente diferentes nos dois grupos, tiveram correlação positiva com os ângulos de hálux valgo e intermetatarsal. Contudo, nem a distância absoluta nem a relativa do sesamoide lateral ao segundo metatarso foram diferentes nos dois grupos, bem como não se correlacionaram com os ângulos de hálux valgo e inter-metatarsal.

Conclusão Apesar do desvio medial do primeiro metatarso no hálux valgo, o sesamoide mantém sua relação com o segundo metatarso no plano transversal. Esse aparente deslocamento lateral pode levar a interpretação equivocada dessas radiografias. Tal fato é de suma importância no pré-, peri- e pós-operatório dos pacientes com hálux valgo.

Palavras-chave

- hallux valgus
- ossos do metatarso
- radiografia
- análise estatística

Introduction

Hallux valgus (HV) is a highly prevalent foot deformity, affecting 23% of the adult and 35.7% of the elderly population.¹ It is one of the most common foot-related complaints in patients seeking for specialists help at the foot and ankle surgery service. It predominantly affects adult women. It has multiple causes, both intrinsic and extrinsic.^{2,3} In addition, clinical manifestations can vary according to the anatomical elements involved. Although it is a disorder known for centuries,⁴ it is complex and its treatment is not yet fully standardized, as demonstrated by hundreds of surgical techniques described in the literature, mostly with inconsistent results.^{5,6}

The hallux sesamoid bones are accessory bones of the foot that are fundamental to the physiological functioning of the first metatarsophalangeal joint. They potentiate the force of the short flexor hallucis muscle, act as “fulcrum” and are located under the head of the first metatarsus, attached to the base of the first proximal phalanx by the plantar plate.⁴ The lateral displacement of the sesamoids is often found in feet with HV. Such deviation has been recognized since the beginning of this century, when it was believed that the sesamoids realignment to their normal position was a criterium for a successful surgery.⁷ Although it was not fully explained, it was already observed that the lateral migration of the sesamoids in relation to the head of the first metatarsus played an important anatomical and functional role both in the initial development and progression of the condition and in the potential of postoperative recurrence.⁸

Despite the lengthy study of the metatarsophalangeal joint in the genesis and progression of the hallux valgus, few scientific researches characterized its mechanics and contribution to HV.⁸ As a result, the evaluation of the sesamoid bones position in the first metatarsophalangeal joint remains in evidence, given its importance for the diagnosis, treatment and recurrence of HV.

The present study aimed to determine if the sesamoid bones migrate laterally in the feet with HV or if they only appear to move, resulting in wrong radiological interpretations.

Material and Methods

Patients

This is a retrospective study with patients treated at a single orthopedic care service. All patients seen in the orthopedic sector due to HV or other foot conditions from 2015 to 2016 were eligible to participate in the study. Patients younger than 18 years-old, in addition to those with foot deformities, open growth plate, infection, history of trauma or previous surgery were excluded.

The feet of the patients were radiographed in anteroposterior (AP) view, according to Rosenberg,⁹ that is, in the orthostatic position, with the X-ray tube at a 15° angle in relation to the vertical axis, centralization over the navicular bone and focus-film distance of one meter. Feet with hallux valgus angle (HVA) higher than 15° were classified as HV deformity, whereas those with HVA lower than 15° were considered normal (control).



Fig. 1 Measurements of the sesamoid relations to foot bones. Line A – axis of the proximal phalanx; Line B – length of the second metatarsus; Line C – distance between the head of the first metatarsus and the axis of the second metatarsus; Line D – distance between the center of the lateral sesamoid bone and the axis of the second metatarsus; Line E – axis of the first metatarsus; Line F – axis of the second metatarsus. The hallux valgus angle is formed by lines A and E, and the intermetatarsal angle is formed by lines E and F.

Measurements

The measurements were performed with the PACS digital system by two authors (MD and GE). The HVA was measured between the first metatarsus axis and the proximal phalanx-axis, and the intermetatarsal angle (IMA) was measured between the first metatarsus and the second metatarsus axes (► **Fig. 1**). The proximal phalanx-axis was drawn through the

center of the proximal articular surface and the center of the distal epiphyseal end. The second metatarsus axis was drawn through the center of the distal articular surface and the center of the proximal diaphyseal end. Lastly, the first metatarsal bone was drawn to connect the center of the head to the center of the metatarsal base, as described by Miller.¹⁰ The position of the lateral sesamoid bone in relation to the second metatarsus (PSM) was defined as the shortest distance from the center of the lateral sesamoid bone up to the second metatarsus axis. The position of the first metatarsus relative to the second metatarsus (PMM) was defined as the shortest distance from the center of the first metatarsal head to the second metatarsal axis. To accommodate the different feet sizes, the lateral sesamoid bone deviation coefficient (LSDC) and the metatarsus deviation coefficient (MDC) were defined.

$$\text{LSDC} = \text{PSM}/\text{LM} \text{ and } \text{MDC} = \text{PMM}/\text{LM}$$

Considering LM as the longitudinal length of the second metatarsus.

Measurements Reliability and Statistical Analysis

The HVA, intermetatarsal angle (IMA), PSM, PMM and LM from all studied feet were independently measured by two authors (MD and GE). Interobserver correlation was calculated to determine the reliability of the measurements (► **Table 1**).

The PMM, MDC, PSM, LSDC and LM measurements were made and compared between the two groups (HV and control) by means of the Student *t*-test, Mann-Whitney test and, in some cases, the Kolmogorov-Smirnov test. The correlations of PMM, MDC, PSM, LSDC and LM with the HVA and the IMA were made using the coefficients and Pearson correlation matrix. All data agreed with the assumptions of the tests used in their analyses (► **Table 2**). *P*-values lower than 0.05 were considered significant. Data were analyzed with the statistical software XLSTAT.

Results

Demographics

Among the 80 patients (94 feet), 48 feet (nine from men and 39 from women) had HV. In this group, the mean age was 49.25 years-old (ranging from 18 to 86). The remaining 46 feet (11 from men and 35 from women) had no HV and constituted the control group. The mean age was 47.17 years-old (ranging from 18 to 88). There were no statistical

Table 1 Reliability of interobserver measurements at lateral sesamoid bone position in hallux valgus

| Measurements | Interobserver correlation (Hallux valgus) | Interobserver correlation (Normal foot) |
|---|---|---|
| Hallux valgus angle | 0.723 | 0.244 |
| Intermetatarsal angle | 0.987 | 0.795 |
| Position of the lateral sesamoid bone (PSM) ^a | 0.269 | 0.511 |
| Position of the head of the first metatarsus (PMM) ^b | 0.683 | 0.862 |
| Length of the second metatarsus | 0.472 | 0.381 |

^aDistance between the center of the lateral sesamoid bone and the axis of the second metatarsus.

^bDistance between the center of the head of the first metatarsal bone and the axis of the second metatarsus.

Table 2 Measurements in hallux valgus feet and normal (control) feet

| Measurements | Hallux valgus group (n = 48) | Control group (n = 46) |
|--------------|------------------------------|------------------------|
| HVA (o) | 30.5 (15–54.65) | 8.1 (5.5–15) |
| IMA (o) | 13.5 (6.25–18.3) | 11 (3.75–14.85) |
| PLS (mm) | 15.25 (13.25–24.2) | 14.1 (13.45–20.45) |
| PHM (mm) | 25.4 (20.8–38.9) | 20.5 (18.3–29.55) |
| LM (mm) | 74.5 (61–89.5) | 72.75 (64.5–88.15) |
| LSDC | 0.219 (0.17–0.273) | 0.216 (0.181–0.295) |
| MDC | 0.375 (0.299–0.478) | 0.331 (0.269–0.402) |

Abbreviations: HVA, hallux valgus angle; IMA, intermetatarsal angle; LM, length of the second metatarsus; LSDC, lateral sesamoid bone deviation coefficient (PSM/CM); MDC, first metatarsus deviation coefficient (PMM/CM); PHM, position of the head of the first metatarsus; PLS, position of the lateral sesamoid bone.

differences regarding age or gender between both groups ($p = 0.891$ and $p = 0.245$, respectively).

Measurements and Reliability

Mean differences between the two examiners were not different from zero according to the Student *t*-test in both groups (HV and control), which led to the conclusion that there were no statistical differences in the results of the examiners' measurements ($p > 0.05$). The absolute distance between the first and second metatarsus (PMM) and the coefficient calculated to equalize feet size variations (MDC) showed a significant difference between both groups (HV and control). Both values were higher in the HV feet, indicating a displacement of the first metatarsus in relation to the second metatarsus. In addition, both PMM and MDC correlated positively with the HVA and IMA, that is, the higher the PMM or MDC values, the higher the HVA and IMA values (PMM-HVA, $r = 0.579$, $p < 0.0001$; PMM-IMA, $r = 0.630$, $p < 0.0001$; CDM-HVA, $r = 0.394$, $p = 0.006$; CDM-IMA, $r = 0.682$, $p < 0.0001$).

In addition, neither the distance from the lateral sesamoid bone to the second metatarsus (PSM) nor the coefficient calculated to control foot size variation (LSDC) showed a statistically significant difference between both groups. The measured values did not increase in the HV feet, indicating that the lateral sesamoid bone remains relatively stable in relation to the second metatarsus. Moreover, neither PSM nor CDSL measurement correlated with HVA and IMA (PSM-hva, $r = 0.184$, $p = 0.21$; PSM-IMA, $r = 0.173$, $p = 0.24$; CDSL-HVA, $r = 0.07$, $p = 0.639$; LSDC-IMA, $r = 0.126$, $p = 0.395$).

Discussion

During HV development, there is a progressive imbalance of the structures forming the forefoot. In this way, the abductor hallucis tendon is plantarly displaced, and the intrinsic plantar cuff (consisting of the adductor hallucis, flexor hallucis and abductor hallucis muscles), as well as the extensor hallucis longus muscle, moves laterally and becomes an adduction force in the hallux.^{5,11} Continuous

lateral rotation of these structures leads to the lateral displacement or rotation of the sesamoid bones in relation to the plantar surface of the first metatarsus.¹²

However, in fact, we believe that the first metatarsus is medially deviated by the development of HV, while the sesamoid bones remain attached to the second metatarsus. Due to this relationship between the sesamoid and the metatarsal bones, different methods of radiographic evaluation have been used in attempts to stage and standardize their position and displacement within this condition. Both AP and tangential radiographs of the feet are described.^{12,13} However, HV is a comprehensive deformity, involving the entire forefoot. In addition, as far as we know, these studies could not find the correct relation between the sesamoid bones and the rest of the foot, including the lateral rays, in HV.¹⁴ The systematic and mathematic description of this relation can help to characterize the deformity in the first metatarsus and other foot rays.

Since the second metatarsus is closer to the sesamoid bones and it often represents the axis of the forefoot, it was chosen as a landmark in our study. The position of the lateral sesamoid center and the head of the first metatarsus with and without HV was analyzed in relation to this landmark. Several studies have found that tangential radiographs with foot load appear to be better for assessing sesamoid subluxation, since the medial metatarsal rotation in HV may alter the perceived displacement between the sesamoid bones and the first metatarsus in AP radiographs with foot load.^{8,12,13} However, none of these studies showed a change in the relation between the sesamoid bones and the lateral metatarsal bones. In contrast, the need for metatarsophalangeal joint dorsiflexion in the tangential view may alter the position of the sesamoid bones under the first metatarsus.¹³ Therefore, an AP radiographic view with foot load was selected to avoid this problem and facilitate HVA and IMA measurement.

Although sesamoid subluxation may eventually occur in HV, the PSM was not significantly higher in the HV group compared with the control group. Moreover, this distance did not correlate with either HVA or IMA. However, in the HV group, the distance between the first and second metatarsal bones (PMM) was significantly higher than in the control group. This distance was also positively correlated with HVA and IMA. In addition, the relative distances of these measurements (MDC and LSDC) showed the same relation as the absolute distances (PSM and PMM) between the two groups. We also believe that such measurements (LSDC and MDC) may express more objectively these relationships and correlations, since they consider measurements from different sized feet.

Our data showed that sesamoid bones sustain their relationship with the second metatarsus, even in feet with HV. In contrast, the medial displacement of the first metatarsus creates the so-called "sesamoid subluxation." Although this condition has been extensively researched, prospective studies are limited, especially the analysis of the relationship between the lateral sesamoid center and the lateral metatarsal bones on normal (control) or HV feet. Geng et al,¹⁴ as in our study, demonstrated that the lateral sesamoid bone sustains its

relationship with the second metatarsus in the transverse plane. Their study was also performed with AP radiographs with foot loads, both in HV and normal (control) patients. In addition, they corroborate our findings that the standardization of coefficient measurements across different foot sizes shown that the sesamoid maintains its position relative to the second metatarsus, whereas the position of the first metatarsal head is medially displaced on feet with HV.

Saragas e Becker¹⁵ found no significant difference in the distance between the lateral border of the lateral sesamoid bone and the second metatarsus in feet with or without HV. However, these authors did not evaluate the correlation with traditionally measured angles in the feet, such as HVA and IMA. In addition, they also did not calculate the relative distance with the adjustment according to the different foot sizes. Finally, their measurements were from the lateral border of the sesamoid bone. However, since there are irregular protrusions at the lateral border of the sesamoid bone, we believe that this measurement is not always able to achieve the location with the precision and accuracy required for the study.

Huang et al¹⁶ demonstrated that the sesamoid bones location in the HV feet does not change in relation to the second metatarsus after surgical correction. However, these authors also chose the lateral border of the lateral sesamoid bone as a landmark for measurements and they did not compare the sesamoid bone location between feet with or without HV. In addition, we agree with Geng et al¹⁴ in that the comparison of the pre- and postoperative sesamoid bones location can be influenced by the surgical procedure itself or even by the surgeon performing the procedure.

Ramdass and Meyr¹⁷ and Judge et al¹⁸ chose the medial sesamoid bone and the second metatarsus as landmarks on the feet with HV and reported that the distance did not change in the postoperative transverse and frontal planes. However, this distance is greater than the one between the lateral sesamoid bone and the second metatarsus. Thus, we believe that the former is a less sensitive measure of the sesamoid bone location and that it could conceal minor differences.

Katsui et al¹⁹ also studied the alignment of the medial sesamoid bone and the relationship between its poor alignment and degenerative changes in the metatarso-sesamoid joint. Nevertheless, in addition to AP radiographs of the feet, they also used computed tomography images of the feet from patients with HV. They did not evaluate, however, if these changes were also present in feet without HV, since there was no control group. Contrary to our findings, they observed that there was a progressive lateral dislocation of the sesamoid bone according to the increased HV deformity. Similarly, they verified that this lateral sesamoid bone displacement was associated to worse degenerative alterations of the metatarso-sesamoid joint.

When correcting HV, the first metatarsus should be brought back up the sesamoid bones, not vice-versa. Additional soft tissue release procedures are usually required. However, to this day, many surgeons perform this release in different tissues, using different surgical techniques.²⁰ There is no standard or rule.

Conclusion

In conclusion, we did not find a significant change in the lateral sesamoid bone position in relation to the second metatarsus in HV and normal (control) feet. This apparent lateral displacement of the sesamoid bone in feet with HV is a misinterpretation of AP radiographs of the patients' feet. Thus, the sesamoid bones sustain their relationship with the second metatarsus and the medial deviation of the first metatarsus, not the lateral migration of the sesamoid bones, is responsible for the subluxation between the first metatarsus and the sesamoid bones. Therefore, "metatarsal subluxation" could better describe both the metatarso-sesamoid joint subluxation and the misalignment of the first metatarsophalangeal joint.

Conflicts of Interest

The authors declare that there is no conflict of interest.

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