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Original Article

Hallux valgus: a three-dimensional pathology. New therapeutic focus

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Abstract

Objectives: To propose hallux valgus as a three-dimension disease and develop a surgical algorithm for each deformity pattern, incorporating the metatarsal rotation component.

Methods: We prospective evaluated a series of 89 cases from February 2020 to February 2021, of which 80 were women and 9 were men. Mean age was 39 years and mean follow-up duration was 11.3 months. We used the Hardy-Clapham classification system and separated the patients into 2 groups: those with no rotational component (types 1 to 3), and those with a rotational component (type 4 to 7).

Results: Of the cases, 59% belonged to the first group and underwent distal chevron osteotomy, according to deformity degree on the frontal plane. The remaining 41% had a rotational component and underwent distal rotational chevron osteotomy, basal crescentic osteotomy, or modified Lapidus procedure, according to the degree of deformity in the frontal plane or associated instability. Union was achieved in all patients. Furthermore, mean American Orthopaedic Foot and Ankle Society score was 94.5 points, mean visual analog scale was 0.71, and level of satisfaction was 100%.

Conclusion: By considering hallux valgus as a three-dimensional disease, we proposed a treatment protocol appropriate for each patient.

Level of Evidence IV; Therapeutic Studies; Case Series.

Keywords: Hallux valgus/pathology; Hallux valgus/diagnostic imaging; Metatarsal bones; Three-dimensional imaging.

Introduction

Hallux valgus is the most frequent musculoskeletal deformity, affecting nearly 23% of adult patients and 35% of older patients[1]. The physiological angle of the metatarsophalangeal joint is from 12.0 to 15.7 degrees, whereas the reference intermetatarsal (IMTT) angle is from 7.0 to 8.5 degrees[2,3]. Tarsometatarsal laxity and hypermobility of first ray are factors that favor the development of hallux valgus[4]. The first concepts on the role of first metatarsal rotation component in the onset of hallux valgus were introduced in 1956 by Mizuno et al.[5], who developed detorsion osteotomy for its treatment. Subsequently, the relationship between flat foot and first metatarsal rotation was described as a triggering factor of hallux valgus[6].

The metatarsocuneiform joint makes small movements that cause dorsal elevation and pronation during the takeoff phase of the gait. Over time, these small movements may lead to changes in extrinsic muscles and generate tarsometatarsal hypermobility. Instability of this joint results from excessive or abnormal mobility of the first metatarsal head[7].

There is onset of progressive metatarsus primus varus, with an increase both in the first-second IMTT and in metatarsophalangeal angles, often with evident metatarsophalangeal pronation. Lateral sesamoid displacement is actually related to the effect of metatarsal head rotation, with an apparent increase in distal metatarsal articular angle[8]. Radiographically, it is manifested as morphological changes in the first metatarsal head, which is found to have a more rounded appearance[9] and leads to changes in its relation to sesamoid position[10].

Study performed at the Sanatorio de la Trinidad Ramos Mejía, Ramos Mejía, Buenos Aires, Argentina.

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Classically, the severity of hallux valgus is evaluated considering the first-second IMTT, metatarsophalangeal, and distal diaphyseal-epiphyseal angles, all of them measured using front and profile weight-bearing radiographs. None of these incidences take first metatarsal rotation into account. However, if hallux valgus is considered in a three-dimensional manner, one will find that the coronal plane should be studied in another radiological view, such as that proposed by Mortier[11] (Figure 1), or through weight-bearing computed tomography.

Pronation has been mentioned in several publications, but the difficulty in quantifying it has minimized its importance. With the aforementioned radiological incidences, it was possible to incorporate the rotational component as an additional factor in the development of the hallux valgus rather than as a factor of its severity[12]. There is a direct relationship between severity of IMTT angle and metatarsal head rotation. Plane rotation of the first metatarsal is an integral component of hallux valgus and defines the third plane of the deformity[13].

More than 100 surgical techniques have been published for the treatment of hallux valgus[14]. Despite the number of studies and the amount of evidence with regard to the first metatarsal rotation component as part of the disease, the literature does not present clear protocols that incorporate rotation into already standardized treatment algorithms on the best surgical decision for each patient, and what is the influence of the rotational component on the decision towards one technique or another. We aim to present a treatment protocol considering hallux valgus in a three-dimensional manner and proposing a different type of surgery for each deformity pattern, taking the 3 possible planes into account.

Methods

This study was approved by the institutional Research Ethics Committee and was conducted by our team of experts in hallux valgus with specific selection criteria and predefined algorithms, following identical guidelines.

The project was performed in compliance with the ethical standards that regulate human research, according to the National Law of Personal Data Protection Number 25326 (*Ley de Habeas Data*) and to the latest version of Declaration of Helsinki.

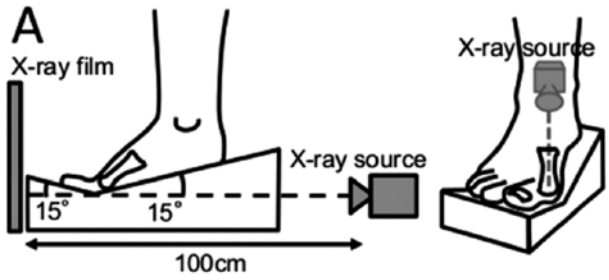

Figure 1. Weight-bearing sesamoid axial view as proposed by Mortier.

We prospectively assessed a case series with a level of evidence IV.

We operated on 89 patients with hallux valgus from February 2020 to February 2021.

Inclusion criteria:

a) Age from 18 to 70 years

b) Painful hallux valgus deformity

c) Preserved metatarsophalangeal mobility (65°-75°)

d) Preoperative American Orthopaedic Foot and Ankle Society (AOFAS) score below 49 points, which ensures that the metatarsophalangeal joint is a painful and/or the patient presents with a mechanical limitation of the forefoot.

Exclusion criteria:

a) Patients with rheumatic disease

b) Hallux metatarsophalangeal arthritis diagnosed in simple radiographs.

c) Previous hallux valgus surgery

Of the patients, 89.8% were women (80 patients) and 11.2% were man (9 patients). Mean age was 39 years (range, 18-70). Mean postoperative follow-up duration was 11.3 months (range 16.2-6 months).

All cases were studied with weight-bearing frontal and profile radiographs associated with axial sesamoid view as proposed by Mortier. In the frontal radiograph, we used the Hardy and Clapham classification system[2] (Figure 2), which is based on tibial sesamoid position in relation to a diaphyseal line of the first metatarsal.

In this incidence, the tibial sesamoid has 7 possible positions, and they were assessed together with sesamoid axial view. When comparing the semiological study of the foot with both views to determine a surgical criterion, we observed that radiological sesamoid positions 1 to 3 do not present with an evident rotational component of the first metatarsal, whereas positions 4 to 7 do present with this component. In the sesamoid axial radiograph, we traced a reference line from the center of the metatarsal head tangential to the horizontal plane (floor) and another from the center metatarsal head to the metatarsal ridge. In this way, we measured the degree of first metatarsal rotation and the degree of required correction; furthermore, we recorded whether medial sesamoid position surpassed (types 5 to 7) or did not surpass (type 1-3) the ridge.

We designed a treatment protocol that divided patients participating in this study into 2 groups (Figure 3), according to medial sesamoid position in the described radiological incidences.

1. Position 1 to 3: there is no significant rotational component. Osteotomy was performed according to angle values shown in frontal radiographs. Distal chevron osteotomy.
2. Position 4 to 7: the deformity has a rotational component. These patients underwent rotational osteotomy, which we selected according to deformity values in the frontal plane, or metatarsocuneiform arthrodesis in case of metatar-

socuneiform joint instability. The procedure of choice will be rotational distal chevron osteotomy, crescentic osteotomy if required according to angular values and in case of stable metatarsocuneiform joint, or modified Lapidus procedure[15] in case of unstable metatarsocuneiform joint. Instability was defined as sagittal mobility of 1 cm on clinical examination[16] or correction of 8° in the coronal plane on tapping radiographs[17].

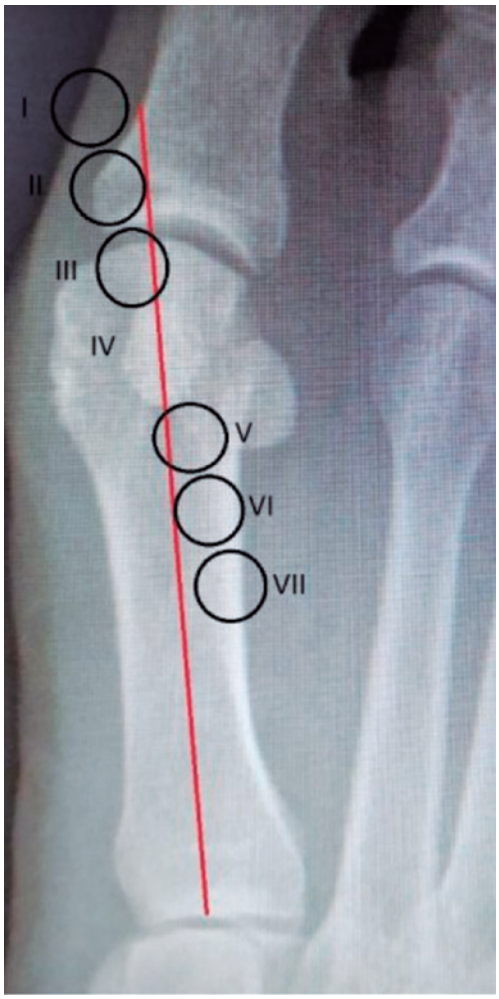

Figure 2. The Hardy and Clapham classification system.

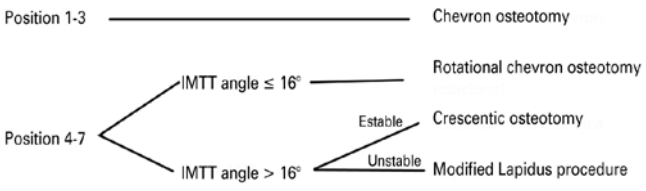

Figure 3. Integrated algorithm for the treatment of hallux valgus.

a. IMTT angle smaller than 16°: rotational Chevron osteotomy
b. IMTT angle greater than 16°.
   1. with no instability: crescentic osteotomy
   2. with instability: modified Lapidus procedure

Rotational chevron osteotomy was performed as described by Prado et al.[18], consisting of a chevron osteotomy with a 90° angle between vertical and horizontal branches. According to the first metatarsal rotation angle, a second osteotomy was performed parallel to the horizontal branch with an internal base wedge (Figure 4). Detorsion osteotomy was performed in all patients through medial approach with bunion resection, chevron osteotomy with medial wage resection and fixation with a 3.0 mm double-thread Herbert or Barouk screw. Lateral capsular and tendon releases were conducted jointly through the same medial approach. First phalangeal Akin osteotomy was performed and then fixed with screw or suture (according to surgeon's preference). Patients used postoperative sandals within the first 24 to 48 hours, according to tolerance, and then used them for up to 30 days.

The parameter for correction is the first metatarsal rotation degree obtained in the weight-bearing axial view, in which a line is traced tangential to the center of the metatarsal head at the horizontal plane (floor), and another line is traced from the center of metatarsal head to metatarsal ridge. Correction was performed with 2-mm base wedges and was systematically reviewed with intraoperative control radioscopy to corroborate final sesamoid position and metatarsal head shape on frontal radioscopy.

Figure 4. Rotational distal chevron osteotomy. Internal base wedge.

Crescentic osteotomy was performed using a single medial wide approach, bunion resection, transarticular release of the lateral capsule and of the conjoint tendon. The procedure was performed at 1.5 cm from the joint, involved displacing and rotating the metatarsal head, and was monitored with radiographs. We measured IMTT angle correction and sesamoid position under the metatarsal head. Osteotomy was fixed with 1 compression screw and a 2.7 neutralization plate with 2 proximal screws and 2 distal screws. Akin osteotomy was also performed. Preoperative sandals were used according to patient tolerance for 30 days.

Regardless of the surgical technique used in the first metatarsal, the 89 operated patients underwent associated first phalangeal Akin osteotomy, which was stabilized with a cannulated screw or with suture, depending on surgeon's preference.

Postoperative controls radiographs were performed at 7, 30, 45, 60 and 90 days, considering medial sesamoid position and first metatarsal rotation (weight-bearing axial view).

Results

Eighty-nine patients with hallux valgus underwent surgery, all of which had a preoperative AOFAS score below 49 points. On frontal radiographs, 53 patients (59.5%) had their sesamoid position classified as 1-3 and underwent traditional distal chevron osteotomy, whereas the remaining 36 patients (40.4%) had their sesamoid classified as 4-7, thus showing a rotational component. Of the latter group, 33 patients (37 %) had an IMTT angle smaller than 16 degrees and were subjected to detorsion chevron osteotomy (Figure 5). Of the other patients, 2 (2.2 %) had an angle greater than 16° with stable tarsometatarsal joint and underwent crescentic osteotomy. Only 1 patient (1.1%) presented with arthrosis and tarsometatarsal instability, which was resolved with a modified Lapidus procedure.

We observed 2 constant semiological characteristics in hallux valgus with a rotational component. One of them is evident hallux nail rotation compared with the other toes. The other one is medial hyperkeratosis at the level of the hallux interphalangeal joint (Figure 6).

All patients showed signs of radiological osteotomy union at 45 days in the cases subjected to chevron osteotomy and to crescentic osteotomy (Figure 7) and at 60 days in the case subjected to modified Lapidus procedure, and union was followed-up on control radiographs obtained during the postoperative period.

There were no immediate postoperative complications. Although postoperative time for this type of disease is short, no recurrences were reported so far.

Mean postoperative AOFAS score was 94.5 points (range, 77-100). Mean visual analog scale (VAS) was 0.71. When asked whether they would undergo surgery again and whether they were fully satisfied with the procedure, patients expressed a level of satisfaction of 100%.

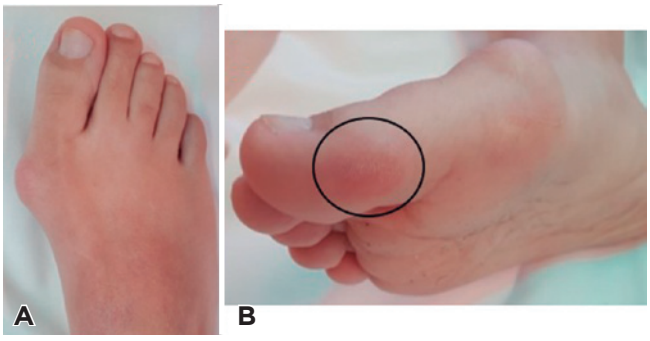

Figure 6. Clinical characteristics of the rotational component.

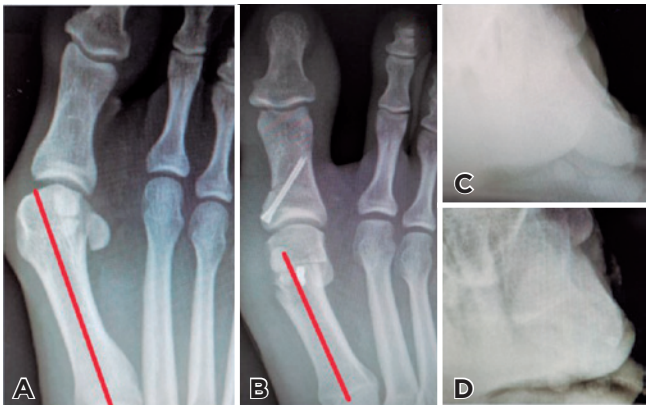

Figure 5. A) Preoperative frontal radiograph showing sesamoid in position 7. B) Postoperative radiograph after rotational chevron osteotomy to correct sesamoid position 3. C and D) Pre-and postoperative weight-bearing sesamoid axial view, respectively.

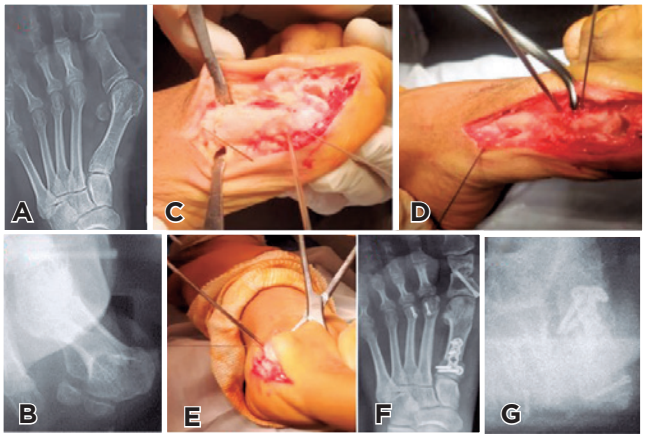

Figure 7. Crescentic osteotomy. Pre- and postoperative radiographs. Images of the surgical technique.

Discussion

In 1980, Scranton and Rutkowski[19] described radiographic axial images of sesamoids in cadavers. Years later (1996), Saltzman et al.[20] analyzed weight-bearing tangential radiographs of sesamoids, in order to assess first metatarsal rotation. In 1998, Talbot and Saltzman[21] investigated whether weight-bearing frontal and tangential radiographs of sesamoids would be sufficient to measure sesamoid subluxation. During decades, sesamoid luxation or subluxation were considered as triggering factors for the rotational component. It has been demonstrated that rotation is produced in the first metatarsal, whereas the sesamoid ligament – second metatarsal maintains the sesamoid complex in position, despite first metatarsal rotation and metatarsus primus varus[10], with the re-emergence of concepts involving first metatarsal rotation, as observed in recent publications[9,10,18,22,23]. Currently there is no doubt that first metatarsal displacement is the origin of sesamoid "subluxation". We analyzed frontal standing radiographs of the foot and sesamoid axial radiographs, both weight-bearing, paying special attention to medial sesamoid position in relation to the first metatarsal medial line (according to the Hardy and Clapham classification system). As it usually occurs when a new concept is incorporated, this concept tends to gain prominence minimize other variables that have already shown to participate in disease onset. Many recent studies[24,25] describe a trend of treating most patients with base osteotomies or metatarsocuneiform arthrodesis rather than with distal osteotomies, which have been performed for many years with excellent outcomes.

In our series, it was observed that 40.4% of cases of hallux valgus presented with first metatarsal rotation before surgery, which was objectively shown both clinically and radiologically. The importance of this percentage mainly lies in 2 concepts. The first of them is the rate of recurrence and poor outcomes[22], due to lack of correction of tibial sesamoid position and of first metatarsal pronation, which is why these 2 elements should be considered in hallux valgus correction. There are no studies in the literature evaluating the association between the Hardy and Clapham classification system and sesamoid measures. The second concept is that the remaining 59% of cases do not have a significant rotational component and thus may be treated with corrective osteotomies that do not involve the rotational component.

The literature did not show any assessment on the potential for rotational correction with horizontal and medial base subtraction wedge in distal osteotomy. We analyzed 5 cadaver bones and measured the correction according to the width of the base subtraction wedge. Each 1 mm of base led to a 2° to 3° of correction.

Relapse or recurrence is usually interpreted based on technical errors, such as insufficient capsular closure force, undercorrection with the osteotomy, or errors in the indication of the type of osteotomy, among other causes. We found that many patients with clinical and/or radiologic recurrence of hallux valgus present with first metatarsal rotation, a fact that is consistent with tibial sesamoid position 4 or greater[4]. The study published by Wagner and Wagner[9] assessed the variables that are associated with deformity recurrence and demonstrated that the most important variable is tibial sesamoid position. Another study found that recurrence rates increase when sesamoid position is 4 or greater (position 4: 50% of recurrence; position 5 or greater: 60% of recurrence)[23].

Although postoperative time of these patients is short and it is not possible to state that none of them will present with recurrence, there were no reports of recurrence of hallux valgus so far. We have investigated whether weight-bearing frontal radiographs and sesamoid axial radiographs are sufficient and appropriate to plan hallux valgus surgery by comparing these radiographs with weight-bearing computed tomography, which has been increasingly used nowadays.

Conclusion

Concepts on rotational deformity are essential to plan hallux valgus correction in a three-dimensional manner; thus, we designed an algorithm that contemplates them in the treatment of this disease. This algorithm provides a specific treatment for each degree of displacement and rotation, which may lead to successful results in all variables of this very frequent disease.

Authors' contributions: Each author contributed individually and significantly to the development of this article: DY *(https://orcid.org/0000-0002-9542-6914) Conceived and planned the activities that led to the study, performed the surgeries and bibliographic review; IM *(https://orcid.org/0000-0002-9452-0175) Performed the surgeries, interpreted the results of the studies and data collection; FA *(https://orcid.org/0000-0001-6577-8911) Participated in the review process, bibliographic review and formatting of the article; SS *(https://orcid.org/0000-0003-0432-8102) Clinical examination, interpreted the results of the study and approved the final version; JD *(https://orcid.org/0000-0002-5733-6766) Performed the surgeries, clinical examination and statistical analysis. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID)

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