Role of coronal plane malalignment in Hallux Valgus correction

Introduction

Hallux Valgus pathology is a multiplanar deformity. The classic description in books of Hallux Valgus has been for a long time just a transverse plane deformity. Only recently, the concept that the deformity is present at multiple levels is getting more common. A coronal malalignment is present in almost 90% of patients (1) at variable degrees. It consists in metatarsal pronation (external rotation) in addition to rotation of the sesamoid complex and the great toe itself. This coronal malalignment can be seen on x-rays, but even during physical examination great toe pronation can be evident.

Importance and mechanics

When a new factor or characteristic is described for a certain pathology, it is of real importance only if it changes the patient outcomes and/or surgical results. If it doesn´t, it helps just with a deeper understanding of the problem, but with no real impact on our patients (which should be our final goal as physicians). Regarding metatarsal coronal malalignment in Hallux Valgus patients, it has a real impact on patients given that it affects patient outcomes and deformity relapse rate. As shown by a number of authors, the recurrence rate after Hallux Valgus surgery ranges from 30 up to 70% in the long term (2 – 6). The factors that influence Hallux valgus recurrence after realignment surgery are between others: larger preoperative Hallux valgus (> 40 degrees) and intermetatarsal angles, larger postoperative Hallux valgus >8 degrees and intermetatarsal angles,

tarsometatarsal instability, flatfoot, juvenile hallux valgus, postoperative altered DMAA, metatarsus adductus > 23 degrees, postoperative sesamoid position >3 and positive lateral metatarsal head round sign (2,7-11). These factors can be summarized as the magnitude of the preoperative and postoperative IMA and HVA, presence of metatarsus adductus, persistent postoperative abnormal DMAA, tarsometatarsal instability and postoperative persistent pronation of the medial ray.

As said previously, 87% (1) of patients have medial ray pronation. In patients without Hallux Valgus, pronation can measure up to 14 degrees. On the other hand, in Hallux Valgus patients the mean is significantly higher (22 degrees). The pronation of the medial ray has been identified by some authors as an important recurrence factor. In fact, Shibuya et al (2) identified it as the most important relapse factor. They published a recurrence rate of 51% when the postoperative sesamoid position was >4 following the Hardy and Clapman classification, and 60% if the sesamoid position was >5. Similarly, Kaufmann et al (8), demonstrated the sesamoid position to be a significant relapse factor. Park (7) showed that sesamoid position can even be a relapse factor identified in immediate postoperative non-weight bearing radiographs. The first publications that identified postoperative persistent first ray pronation as a Hallux Valgus relapse factor were two studies by Okuda et al (12,13). One focused on sesamoid incomplete postoperative reduction and the other on metatarsal bone pronation. Chen et al (14) published that first ray persistent pronation was significantly associated to worse outcomes (AOFAS score) and more dissatisfaction (OR=3). Other important factor that influence postoperative functional scores is depression (15). Katsui et al (16), showed a

direct relationship between an increasing (more lateral) medial sesamoid position (increasing pronation) and worsening degenerative changes at the sesamoid-metatarsal joint on CT. They showed too, that there was a direct relationship between lateral shift of the sesamoid complex and increasing Hallux Valgus deformity. Kim et al (1), on the other hand, did not demonstrate that direct relationship.

From a biomechanical standpoint, it is not known whether pronation occurs before, after or simultaneously with the first metatarsal varus. When the metatarsal rotates, the sesamoid complex rotates in conjunction given their mutual multiple ligamentous attachments. As the sesamoid complex is congruent to sesamoid facets on the metatarsal and continuous with the medial capsule and deep intermetatarsal ligament, during the initial pronation, the sesamoid complex rotates following the metatarsal, without dislocating from its facets. In long standing Hallux Valgus, dislocation of the sesamoid complex from the metatarsal sesamoid facets can occur, given an intermetatarsal ligament and adductor tendon contracture, a loose medial capsule and the constant lateral pull of the flexor hallucis longus tendon (FHL) (17,18,19). The FHL traverses between the sesamoids and inserts into the distal phalanx. If the sesamoid complex is pronated-lateralized in a Hallux Valgus patient, the FHL tendon will constantly pull the great toe into valgus, progressively increasing the deformity and/or contributing to Hallux Valgus relapse. (FIGURE 1).

Regarding the relation between metatarsal pronation and sesamoid subluxation, Kim described 4 different combinations. The most common type was to have metatarsal pronation and sesamoids subluxation (61%). The second most common was to have

metatarsal pronation, but no sesamoids subluxation (26%) (sesamoids remained in their facets). The remaining 13% included cases without pronation, but with sesamoids subluxation and cases with neither pronation nor sesamoids subluxation. It is important to note, that when treating hallux valgus, pronation correction will not necessarily reduce sesamoids to their facets, especially if a long-standing dislocation and/or deformity is present. To reduce them, a soft tissue procedure on the metatarso-sesamoid ligament and intermetatarsal ligament should be performed.

Diagnosis

First ray pronation (external rotation) can be diagnosed in several ways. On physical examination, a pronated Hallux is easily seen, frequently associated with a callus on the medial Hallux**.** Of course, this is a subjective and inaccurate method, but its positive predictive value is extremely high for first ray pronation. On radiological examination, weight bearing axial sesamoid view is a better method. It gives you a good view of the sesamoid functional position related to the metatarsal. Nevertheless, based on the authors 5 years-experience using this image, this diagnostic method has a serious flaw: It is technically very difficult and inconsistent to take. Given that the x-ray cassette should be perpendicular to the first metatarsal axis, it is impossible to have a standardized view, given that different degrees of deformity exist in every patient depending on the Hallux valgus severity, and therefore, multiple x-ray positions should have to be considered. In addition, the foot position is not comfortable for patients, fact that gives even more

variability and less reliability to this x-ray projection. These are the reasons why the authors do not recommend this view anymore for a reliable pronation measure, classification method or treatment decision. Kim et al (1) compared simulated weight bearing CT scan and sesamoid x-rays and found that in 38% of the cases the X-ray and CT values differed. Therefore, they did not recommend the axial sesamoid view as well. The gold standard for metatarsal pronation and varus measurement is a weight bearing CT scan (WBCT). The measurement technique takes into account the metatarsal plantar and dorsal cortices to estimate the bone rotation (1). Even though this is a good method, the authors recommend a different and simpler measurement method. The angle is measured between a line through the sesamoids facets and the floor line. This a straightforward and fast technique and takes into account the functional axis of the metatarsal (sesamoids facet), and not the just the bone anatomy. Another pronation measurement method considers using the AP foot weight bearing view. This method was already published (20) and is summarized as follows. It divides pronation in three stages: 10-20 degrees, 20-30 degrees and >30 degrees. It is based on the metatarsal head lateral round shape. This roundness represents the metatarsal condyles that are visible laterally given the metatarsal rotation. In stage 1 (10-20 degrees) the lateral first metatarsal head shape is rounded, but a step from the condyle to the joint line can be seen (Figure 2). For stage 2 (20-30 degrees), a continuous line from the joint line to the metatarsal condyles can be seen, but it does not form a perfectly round shape (Figure 3). For stage 3, the metatarsal condyles line and the first metatarsal head are completely round (Figure 4). The validation of this pronation measurement method compared with weight bearing CT scan is under

publication, having a good inter and intraobserver reliability score and a good performance regarding sensitivity and specificity for each stage.

Treatment options

Surgical options that include metatarsal external rotation correction capabilities are POSCOW osteotomy (21), proximal metatarsal dome osteotomy (22), Lapidus procedure (23) and PROMO (20, 21, 24, 25). These will be briefly explained in the following paragraphs.

POSCOW osteotomy is a sliding, oblique and closing wedge osteotomy, through which pronation can be corrected. The main drawback of this osteotomy is its inherent instability due to its vertical orientation, and therefore weight bearing protection has to be recommended for 6 weeks. The same happens with the dome osteotomy. It is a very powerful osteotomy, but it is unstable given its geometry. Lapidus procedure is another technique that has metatarsal rotation capabilities. Through the tarsometatarsal fusion, severe deformities can be corrected. The main drawbacks of this technique are the fact that most of the time we are fusing a healthy joint, and that in order to achieve fusion, the first ray is shortened (minimum 5 mm). Restricted tarsometatarsal (TMT) motion after a Lapidus procedure can increase the plantar pressure beneath the first ray (up to 37% increase in mid stance). An increase in contact pressures can also be found in the naviculo-cuneiform joint (27%) and fifth metatarso-cuboid joint (40%). (26) Second metatarsal stress fractures may also occur due to stress increase in the second metatarsal bone after a Lapidus procedure, as stresses under the 2nd metatarsal bone can increase up to 22% at

midstance phase of gait. (27) With all Lapidus, at least 5 mm of medial column shortening always happens because of joint preparation. Even more if there is a wedge resection. This shortening has very important mechanical consequences, such as transfer metatarsalgia, lesser metatarsals plantar plate ruptures, cosmetically odd-looking foot (short Hallux), between others. The overall complication rate according to Willegger et al is 16% (28). There is a 30 to 80% of return to activity (sports) reported in the literature (29). For these reasons, fusing a joint (that is absolutely healthy) should not be taken lightly and should be thoroughly studied and analyzed before proceeding with it. The authors only use TMT fusion for severe cases (IMA >18º), arthritic or unstable TMT joints.

Finally, the PROMO procedure (25), is a proximal oblique metatarsal osteotomy, which thanks to the geometrical advantage of being performed in an oblique plane, metatarsal pronation and varus can be corrected without bone resection, only through rotation. (Figure 5) It has a distal-dorsal to proximal plantar direction, being a stable osteotomy under weight-bearing circumstances. Taking into account the intermetatarsal angle and estimating the metatarsal pronation present, a precise osteotomy angle is used for every particular hallux valgus case. Weight bearing is allowed at 3-4 weeks postoperatively once the swelling decreases.

Outcomes

Clinical outcomes of techniques that correct pronation are scarce in the literature. Every hallux valgus article reports about the intermetatarsal or metatarsophalangeal angular

correction obtained, but not about the rotational deformity correction. By our best knowledge, there are no short or medium-term studies published with the Lapidus procedure or POSCOW osteotomy relative to the correction of metatarsal pronation. There are some reports with the proximal crescentic osteotomy (12, 13, 20, 25) and with the PROMO technique showing excellent and very good results. The authors current experience with PROMO includes 60 patients with 1 year follow up and 25 patients with 2 years follow up. We included adult patients with mild and moderate deformities (IMA <17), stable TMT and no signs of arthritis. Regarding complications, we have registered 1 (16 year-old) deformity relapse (at 3 months postop), 1 patient with a medium-term relapse (18 months), 1 distal segment elevation and 1 delayed union (healed at 3 months). No infections have been seen.

Summary-Discussion

Metatarsal pronation correction in Hallux Valgus is of utmost importance if the best treatment is to be given to the patient. It has been shown in different studies how it influences the relapse rate (2,7,8,12,13). Given the high relapse rate shown in some articles at medium-long term for operated Hallux Valgus (30-70%) (2-6), some action should be taken to treat and address all the identified deformity relapse factors. The authors encourage the readers to start looking at the head shape and at the sesamoids location when operating Hallux Valgus patients. We recommend assuming that any metatarsal head which appears to look round on its lateral aspect, has a pronation deformity until proven the contrary. If this is the case, choose the most appropriate technique in order to achieve a complete correction. If the metatarsal and sesamoids are

not realigned, it is a matter of time until the deformity will reappear. Our treatment goal in hallux valgus surgery should be to obtain a stable and balanced medial ray, with no skeletal malalignment or asymmetric tendon pull.

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Figure legends

Figure 1

AP foot weight bearing Xray of a postoperative Hallux Valgus. As in all scarf, there was no pronation correction. The sesamoid complex is still lateralized, and the head shape is still round laterally. The FHL is lateral to the medial ray axis, therefore, a continuous lateral soft tissue pull exist on the great toe.

Figure 2

AP foot weight bearing X-ray. In stage 1 pronation (10-20 degrees), the lateral first metatarsal head has a step from the condyle to the joint line (arrow).

Figure 3

AP foot weight bearing X-ray. In stage 2 pronation (20-30 degrees), a continuous line from the joint line to the metatarsal condyles can be seen, but it does not form a perfectly round circle-shape (arrow).

Figure 4

AP foot weight bearing X-ray. For stage 3, the metatarsal condyles line and the first metatarsal head are completely round (a circle can be drawn).

Figure 5

A medial foot drawing is shown. A medial locking plate and interfragmentary screw are positioned stabilizing the PROMO osteotomy. The black oblique line represents the osteotomy.