Review

# Hallux valgus: choosing the appropriate surgical technique

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## Abstract

The frequency of Hallux Valgus deformity in the general population is quite high, thus many orthopaedic surgeons, not only foot and ankle specialists, perform forefoot reconstructive surgery in their daily practice. Highly sophisticated techniques require deep knowledge, experience and completion of the learning curve in order to avoid some of the poorer outcomes documented within the literature. Distal, diaphyseal, metadiaphyseal and proximal types of osteotomies have been described according to the extent of the deformity. Fusion techniques have been modified to offer more predictable results. Frontal derotational osteotomies have been devised to address the metatarsal pronation element of Hallux Valgus pathology. Percutaneous techniques have evolved and are considered a safe solution to a certain and strictly defined spectrum of indications. A table of scenarios on Hallux Valgus deformities and their corresponding surgical treatment is proposed for decision-making. The osteotomy type choice is considered multifactorial and is certainly based on surgeons' experience, training and knowledge of the exact pathology of the deformity.

## Keywords

Hallux Valgus; minimally invasive surgery; PECA; MICA; META; PETA; metatarsus adductus; scarf osteotomy; metatarsal pronation

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## Introduction

The global incidence of Hallux Valgus deformity in the general population is around 19% [1], thus, many orthopaedic surgeons, not only foot and ankle specialists, perform forefoot reconstructive surgery in their daily practice.

It is widely accepted that the spectrum of Hallux Valgus deformities is complex and that a single operation is not suitable for the whole range of indications. Highly sophisticated techniques, such as the versatile open Scarf osteotomy or the 4th generation minimal invasive surgery (MIS) transverse osteotomy, require deep knowledge, experience and completion of the learning curve in order to avoid some of the poorer outcomes documented within the literature (Fig. 1) [2]. Consequently, one has to proceed with extreme caution regarding the type of deformity, along with the appropriate surgical technique selection.

In 1981, Helal counted more than 150 osteotomies to treat Hallux Valgus pathology, underlying the need for multiple osteotomy types to deal with this non-homogenous group of deformities [3]. Few of them are still in use, some have been added, such as the MIS techniques, and others have been devised to address the rotational deformities of the first ray. On the other hand, many of them have been abandoned throughout the years due to their high complication rates such as the original Wilson osteotomy because of the first metatarsal (MT1) excessive shortening and subsequent transfer metatarsalgia [4].

An orthopaedic surgeon has to keep in mind that cosmetically appearing post-operative scars, along with small incisions, are important for satisfaction-based scoring [5]. However, a red line between cosmetic perception and Cinderella surgery, also known as foot-narrowing surgery, should be drawn. Forefoot reconstructive procedures aiming to alter the size and shape of the feet of women in order to fit inside fashion high-heeled shoes should be considered with skepticism, as various and important medicolegal issues can be raised [6].

## Hallux valgus spectrum

Hallux Valgus is a combined multiplanar deformity including valgus deviations of the great toe, known as hallux valgus, varus deviation of the first metatarsal bone, known as metatarsus primus varus and frontal rotational deformities, such as hallux and first metatarsal pronation or supination. The corrective osteotomies should address bony malpositioning in all three planes, transverse, frontal and sagittal, in order to rebalance the sesamoids just beneath the metatarsal head on plain post-operative radiographs and provide a functional and normal-appearing foot.

The development of Hallux Valgus is strongly related to other underlying pathologies or deformities. The rheumatoid population or individuals suffering from neuromuscular conditions, such as Parkinson's disease or cerebral palsy, are generally affected. Cases of metatarsus adductus, pes planus, juvenile Hallux Valgus onset, second toe amputation, first metatarsophalangeal joint (MTP1) arthritis, or general ligamentous laxity leading to first tarsometatarsal (TMT1) joint instability, may require specific forefoot reconstructive strategies.

Roger Mann in the early 1990s described a treatment algorithm based on the size of intermetatarsal angle (IMA) measurement on transverse plane [7]. Mild Hallux Valgus (IMA<13$^{o}$), moderate Hallux Valgus (IMA: 13-15$^{o}$), "gray zone" severe Hallux Valgus (IMA: 16-20$^{o}$), severe Hallux Valgus (IMA>20$^{o}$) and lateral deviation of the articular surface of the MT1 head, called distal metatarsal articular angle (DMAA), with or without loss of joint congruence, are basic parameters that are measured. After this assessment, the indicative reconstructive technique, osteotomy or fusion, in combination with distal soft tissue procedures is chosen.

Mild (IMA<13$^{o}$) and incongruent MTP1 joint (DMMA<10$^{o}$) deformities are simple cases a beginner surgeon should start with, in order to build his learning curve in forefoot surgery (Table 1). An open distal Chevron osteotomy should provide a sufficient corection. However, due to its short plantar orientation cut, high rates of avascular metatarsal head osteonecrosis have been reported. Helmy et al. [8] described a reversed 'L'-shaped distal first metatarsal osteotomy modification, which respects vascularity and preserves the plantar nutrient artery as an alternative to the original Chevron technique, resulting in fewer complications.

For moderate (IMA: 13-15°) and incongruent MTP1 joint (DMMA<10°) deformities performing a distal osteotomy is not considered the ideal option, due to the lack of geometry and limited lateral translation range of the distal first metatarsal fragment. These cases are preferably treated with a metadiaphyseal osteotomy, such as the scarf osteotomy, rather than a Chevron osteotomy.

**Scarf osteotomy**

Scarf osteotomy was popularized by L.S. Weil & S. Barouk [9] in 1992. It's an effective, versatile and reliable procedure, providing strong fixation and allowing early functional recovery.

The corrective scarf z-step osteotomy is not a diaphyseal osteotomy per se, but a metadiaphyseal one. The width of the longitudinal cut extends into the metaphyseal area of the metatarsal bone, both proximally and distally, thus preventing complications associated with troughing, such as limited lateral translation, pronation and elevation of the metatarsal head. "Gray zone" severe deformities (IMA: 16-20°) are suitable for the scarf technique, allowing enough lateral translation of the distal metatarsal fragment. The key point is to perform the transverse cuts perpendicular to the longitudinal axis of the second metatarsal shaft [10]. In that manner, the IMA is corrected and restored to normal, resulting neither in lengthening nor in shortening translation of the first metatarsal bone (Fig. 2).

The advantage of the scarf osteotomy is that it allows combinations of displacements [10]. Axial rotation of the plantar metatarsal fragment in the transverse plane leads to correction of the DMAA without the need for a second separate wedge osteotomy (Fig. 3). Consequently, the scarf osteotomy is considered more advantageous comparatively to the biplanar Chevron osteotomy when dealing with increased DMAA. Biplanar Chevron osteotomy results in first metatarsal shortening and transfer metatarsalgia due to wedge bone excision [11].

**DMMA correction**

Hallux Valgus deformity with a congruent MTP1 joint (DMMA>10°) is more often observed in juveniles, young adults and men [12]. However, the initial suspicion of an increased DMAA as measured in plain radiographs during the pre-operative planning process, is always confirmed during surgery (Fig. 4) and one should not be contented based on plain radiographs solely.

Failure to address and correct an increased DMAA after a first metatarsal osteotomy will result in an incongruent MTP1 joint, thus predisposing to deformity recurrence, MTP1 joint arthritic changes and stiffness [13].

**Severe hallux valgus deformity: osteotomy versus Fusion**

In severe Hallux Valgus deformities (IMA>20°) a debate between choosing a proximal, diaphyseal, metadiaphyseal osteotomy, TMT1 or MTP1 joint fusion exists in the academic foot and ankle community. Data derived from the USA[14], Switzerland[15], and Germany[16] reveal an equal tendency of approximately 50% towards fusion and osteotomy.

Proximal first metatarsal osteotomies, such as the proximal Chevron, crescentic and medial opening wedge osteotomy, provide great lateral translation of the distal metatarsal fragment in order to restore the IMA to its normal values. They seem to be an ideal solution when treating those large IMAs. However, they tend to be inherently unstable, especially in the sagittal plane, resulting in dorsiflexion malunion, delayed union and loss of correction [17].

The modified Ludloff diaphyseal osteotomy is considered an alternative to the scarf osteotomy, especially in cases of IMA>25° and a narrow first metatarsal, where scarf seems inadequate. The Ludloff procedure, as modified by Stamatis et al. [18], with the supplementation of a small locking plate acting as a medial buttress, prevents medial metatarsal drifting, providing extra stability to the osteotomy site.

On the other hand, severe IMA, especially in the older population, does quite well with MTP1 joint fusion with satisfying functional results [19]. The question that arises, is whether a single MTP1 joint fusion is adequate to restore the IMA to its normal

**Table 1.** Primary Hallux Valgus simple scenarios and their corresponding MT1 surgical treatment proposal.

| Clinical scenario | Surgical treatment |
|---|---|
| Mild IMA(<13°) and incongruent MTP1 joint (DMMA<10°) | Distal Chevron osteotomy or MIS transverse osteotomy |
| Moderate IMA(13-15°) and incongruent MTP1 joint (DMMA<10°) | Scarf osteotomy or MIS transverse osteotomy |
| "Gray zone" severe deformities (IMA: 16-20°) and incongruent MTP1 joint (DMMA<10°) | Scarf osteotomy or MIS transverse osteotomy |
| Moderate IMA(13-15°) and congruent MTP1 joint (DMMA>10°) | Scarf osteotomy enhancing DMAA correction |
| "Gray zone" severe IMA(16-20°) and congruent MTP1 joint (DMMA>10°) | Scarf osteotomy enhancing DMAA correction |

**Table 2.** Primary Hallux Valgus advanced scenarios and their corresponding MT1 surgical treatment proposal.

| Clinical scenario | Surgical treatment |
|---|---|
| Severe IMA(>20°) in the older population | MTP1 joint fusion (without additional proximal MT1 osseous procedures) |
| Rheumatoid arthritis | MTP1 joint fusion (without additional proximal MT1 osseous procedures) |
| Moderate IMA and MT1 pronation | MIS transverse osteotomy |
| Severe IMA and MT1 pronation | Lapidus fusion |
| Mild to moderate metatarsus adductus (Sgarlato angle:21-30°) | MTP1 joint fusion |
| Severe metatarsus adductus (Sgarlato angle>30°) | Consult expert's opinion (TMT1 + TMT2 + TMT3 joint fusion) |
| Severe IMA(>20°) in the adult population with widened MT1 | Scarf osteotomy or modified Ludloff osteotomy |
| Severe IMA(>20°) in the adult population with narrow MT1 | Modified Ludloff osteotomy |
| TMT1 joint arthritis with any degree of IMA severity | Lapidus fusion |
| Primary TMT1 joint instability due to generalized ligamentous laxity | Lapidus fusion |
| Severe IMA(>20°) with increased DMAA(>10°) | Lapidus fusion and a distal first metatarsal derotational osteotomy (e.g. Reverdin osteotomy) |

values. Ripstein [20] showed that the combination of a more proximal surgical correction and an MTP1 joint fusion was beneficial in those severe cases. However, the necessity this type of proximal supplementation was not proven by Ripstein's study. Many authors have underlined the fact that after performing a proper MTP1 joint fusion, no additional proximal procedures are required (Fig. 5). The adduction shifting of the first metatarsal is restricted because the flexor, extensor, and adductor tendons are converted from deforming forces to corrective forces [21].

TMT1 joint fusion (Lapidus procedure) is an available solution when treating severe IMA Hallux


***Figure 1:*** *(A) Radiography presenting hallux valgus deformity correction in a female rheumatoid patient after bunionectomy and distal soft tissue procedures alone, without MTP1 joint fusion. (B) Corresponding clinical photo.*

***Figure 2:*** *Intraoperative fluoroscopic image during Scarf osteotomy. Note that the orientation of the guide pins for the distal and proximal transverse cuts is perpendicular to the longitudinal second metatarsal axis and not perpendicular to the longitudinal first metatarsal axis. In that manner, lengthening or shortening of the first metatarsal bone can be avoided.*

Valgus deformities. Although it's the most powerful corrective surgical treatment, high complication rates can occur, such as MTP1 joint nonunion, first metatarsal shortening, IMA overcorrection and deformity recurrence [22]. Indications for Lapidus fusion are generalized ligamentous laxity, metatarsus adductus deformity, TMT1 joint arthritis (Fig. 6) and severe IMA with increased DMAA, without TMT1 joint arthritis [23]. In this case, where the scarf osteotomy is inadequate to fix both IMA and DMAA, a distal first metatarsal derotational osteotomy combined with TMT1 joint fusion can provide satisfactory results. A Lapidus arthrodesis is the indicated procedure in rare cases of generalized ligamentous hyperlaxity where the TMT1 joint is primarily affected and unstable.

The concept of primary TMT1 joint instability has been over-projected through literature in the past. During the 1990s, many papers emphasized the role of TMT1 joint laxity as a prime pathoetiology factor in the onset of Hallux Valgus, and as a result, the Lapidus procedure was popularized [24]. However, recent literature [25] has proven that after IMA reduction with a metatarsal osteotomy, TMT1 joint hypermobility is reduced to normal. The modern hypothesis is that TMT1 joint laxity is secondary due to the pushing effect of the proximal phalanx onto the head of the varus deviated first metatarsal. TMT1 joint stability is affected by first ray alignment and is not an intrinsic characteristic of the joint [26].

**Metatarsal pronation**

During the last ten years, frontal plane rotational deformities have been given the required attention and importance, and thus Hallux Valgus pathology is considered a three-dimensional deformity. Based on computed tomography (CT) scan measurements, the incidence of first metatarsal pronation is approximately 87% in the Hallux Valgus population [27] and it doesn't seem easy to assess in plain radiographs pre-operatively. A round-shaped metatarsal head on post-operative radiographs (positive round sign) [28] represents a metatarsal pronation deformity that has not been addressed. Failure to correct this kind of rotational deformity may lead to unbalanced


*Figure 3:* *(A) Radiographic pre-operative planning – congruent MTP1 joint with increased DMMA:18° in a male adult patient. (B) Post-operative radiography showing the axial rotation of the plantar metatarsal fragment in the transverse plane during Scarf osteotomy in order to achieve normal values of DMAA and subsequently a congruent MTP1 joint after reduction.*

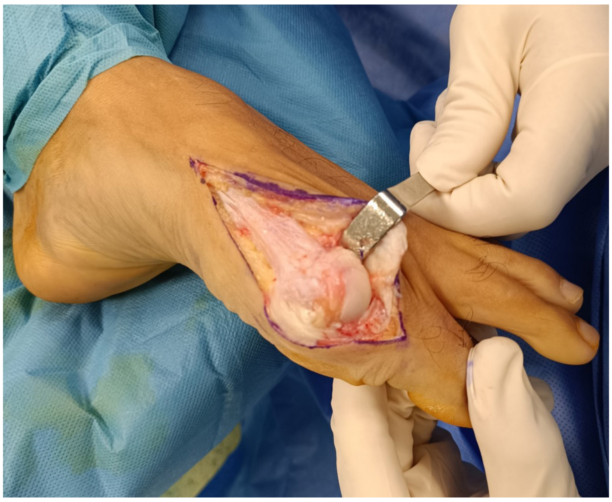

*Figure 4:* *Peri-operative exposure and direct visualization of the first metatarsal head offers exact confirmation of MTP1 joint congruency.*

sesamoid grading and Hallux Valgus recurrence. Sesamoid correction strongly relates to metatarsal pronation [29].

The versatile scarf osteotomy is capable of derotating the first metatarsal and correcting metatarsal pronation by removing a bone wedge from the plantar metatarsal fragment [30]. However, this modification is technically demanding and might be difficult for inexperienced hands.

The Lapidus arthrodesis, the proximal oblique sliding closing wedge osteotomy (POSCOW) [31] and the proximal supination osteotomy supplemented with an X-shaped locking plate as described by Okuda et al. [32] have the potential to correct metatarsal pronation, however, they lack stability, apart from the Lapidus procedure.

Wagner et al. recently presented the Proximal Rotational Metatarsal Osteotomy (PROMO) [33] providing encouraging short-term results. Extended, long follow-up studies are mandatory in order to draw safe conclusions.

**Metatarsus adductus**

Metatarsus adductus is a complex midfoot and forefoot deformity whose onset is in utero. The main characteristic is a large Hallux Valgus Angle combined with mild to moderate IMA. The whole forefoot is adducted at the level of tarsometatarsal joints, and all metatarsal bones, both the first and lesser ones, are medially deviated. Those feet are quite difficult to treat, requiring experienced surgeons. One should seek expert's consultation regarding surgical strategy in these demanding cases. However, identifying this complex deformity on plain weight-bearing radiographs is essential. Calculating the modified Sgarlato angle, a composite measurement between the angulation of midtarsal bones and the longitudinal axis of the second metatarsal bone, is of paramount importance [34]. Values between 10° – 21° are normal, whereas cases with a Sgarlato angle between 21° – 30° are considered mild to moderate and values >30° are severe. No consensus regarding surgical treatment exists. Correcting only the Hallux Valgus deformity in mild metatarsus adductus cases by using a first metatarsal osteotomy will lead to a recurrence rate of between 30%


*Figure 5: (A) Radiography presenting severe hallux valgus deformity (IMA:26°). (B) Post-operative radiography presenting proper MTP1 joint fusion without additional proximal osseous procedures.*

and 80%, thus, this surgical strategy, is not considered the best option[35]. Severe metatarsus adductus can be treated with first, second and third TMT joint fusion in order to realign the hindfoot, midfoot and forefoot (Table 2). In some mild adductus cases, the surgeon can proceed with MTP1 joint fusion in combination with distal Weil or Fowler lesser metatarsal head osteotomies in an effort to realign the forefoot. A combination of reconstruction procedures has also been published using MIS techniques[36].

**Minimally invasive surgery (MIS)**

In the early 2010s, the Educational Committee of EFAS[37] welcomed and applauded MIS forefoot reconstructive techniques as an innovation for improved, safer, and maybe cheaper treatment for patients. However, they expressed criticism and concern about that trend and emphasized the necessity for prospective and randomized trials with long-term results to provide sufficient data regarding the superiority and safety of those techniques. In addition, they projected their worries regarding the over-promotion of industry-guided educational MIS courses before such studies had been conducted.

In 2016, Vernois et al.[38] and Lam et al.[39] introduced their 3rd MIS generation technique, since the first and


*Figure 6: (A) Radiography presenting hallux valgus deformity with TMT1 joint arthropathy. (B) Post-operative radiography presents an inadequate surgical strategy as it does not address the TMT1 joint arthropathy. Such combined Hallux Valgus cases should be preferably treated with Lapidus fusion. (C) Another clinical example. Radiography presenting hallux valgus deformity with concomitant TMT1 joint arthropathy. (D) Post-operative radiography presents the correct surgical approach with Lapidus fusion.*

second generations had been abandoned through literature because of published disappointing results and catastrophic complications[40]. The 3rd generation Minimally Invasive Chevron and Akin (MICA) os-

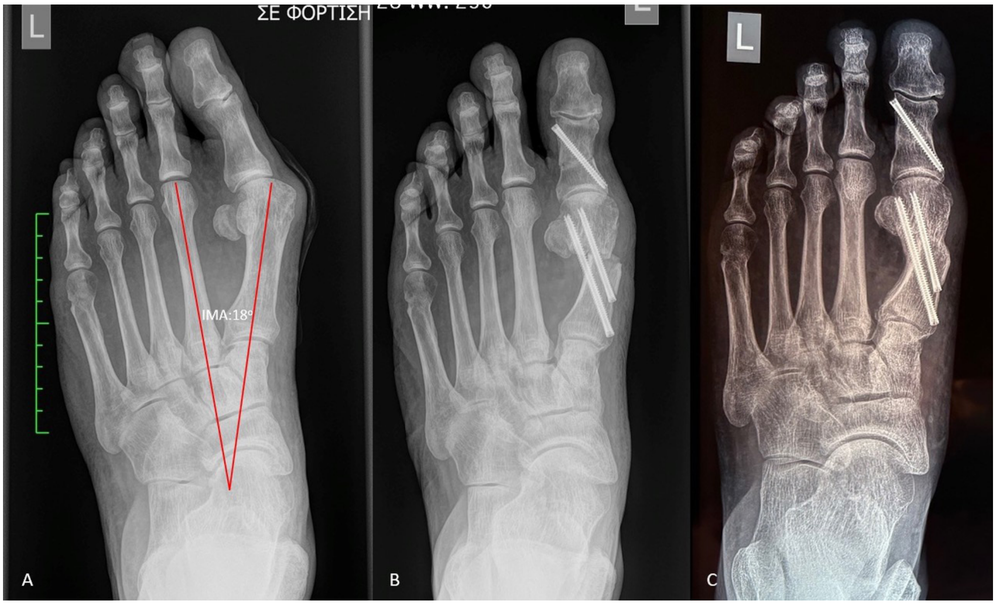


***Figure 7:*** *(A) Radiography presenting "gray zone" severe Hallux Valgus (IMA: 18°) hallux valgus deformity. (B) Post-operative radiography presenting 4th generation MIS distal transverse extra-capsular osteotomy fixed with two non-beveled screws. (C) One year post-operative radiograph of the same foot. Note the secondary bone healing formation inside the displacement site.*

teotomy, named by Vernois, and the 3rd generation PErcutaneous Chevron/Akin (PECA) osteotomy, named by Lam respectively, gained popularity and clinical traction among surgeons in Europe and Australia in patients with mild to moderate Hallux Valgus deformity (IMA<20°) and in strictly selected patients with severe deformity (IMA>20°) [41,42,43,44]. Several level I prospective midterm follow-up publications have shown the adequacy of these methods regarding clinical and radiological outcomes compared to open osteotomies [45]. In addition, post-operative benefits, such as fewer wound complications, reduced swelling, better cosmetic scars and shorter rehabilitation time have also been underlined [46].

In 2020, there was a transition from a percutaneous distal MT1 Chevron osteotomy to a percutaneous distal MT1 transverse osteotomy [44]. This evolution to a 4th generation MIS technique was given several logos, such as Metaphyseal Extra-articular Transverse and Akin osteotomy (META) [47], or PErcutaneous Transverse Akin (PETA) [48], or the new PECA technique,[44] adopting beveled screw fixation. The reason for this osteotomy "switch" was the fact that a transverse cut could more easily address MT1 pronation deformity, providing better bicortical stability and an easier learning curve [49].

However, many questions arise regarding the healing process surrounding the MIS transverse osteotomy site, especially when viewing near 100% bony shift and no osteotomy contact on post-operative radiographs. Concerns about a possible nonunion or delayed union sound logical, on the other hand they have not been justified (Fig. 7). A recent study by Spacek et al. [50] underlines the fact that the 3-dimensional soft tissue pyramid-shaped space, which is created after the extra-capsular MIS osteotomy, between the medial border of the MT1, the osteotomy site, and the preserved periosteum, is vital for the secondary bone healing process through hematoma formation. The osseous healing is therefore maximized with the aid of rigid screw fixation, allowing full weight-bearing post-operatively by applying Wolff's law.

Although recent studies from highly experienced MIS surgeons and meta-analytic data show encouraging, equivalent, or even superior results of 4th generation MIS techniques compared to standard open surgery [51,52], other meta-analytic data do not fully confirm those conclusions [53]. More robust, high-quality, prospective clinical studies, with larger patient numbers, are paramount to obtain more validated data regarding 4th generation MIS techniques and allow further recommendations.

**Conclusions**

Choosing the indicated surgical technique to treat Hallux Valgus deformities is multifactorial. Applying a unique osteotomy that suits all Hallux Valgus spectrum is malpractice, and this is an undeniable truth. The choice is certainly based on surgeons' experience, training and knowledge of the exact pathology of the deformity. Aiming to shorten the learning curve, especially in MIS techniques, by undertaking multiple cadaveric courses is preferable. High-quality and validated evidence through literature is mandatory to draw gold-standard treatment strategies.

**Conflict of Interest**

The authors declared no conflicts of interest.

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