The Foot 38 (2019) 39–42

Contents lists available at ScienceDirect

The Foot

journal homepage: www.elsevier.com/locate/foot

Original Article

Feasibility of open and percutaneous corrective osteotomies of the second phalanx of the great toe: An approach on a cadaveric model

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ARTICLE INFO

Keywords:
Interphalangeal hallux valgus
Percutaneous osteotomies of the distal phalanx of the great toe
Hallux valgus percutaneous surgery
Hallux distal phalanx morphology
Hallux valgus angles

ABSTRACT

Background: Having had a previous experience of 4 open F2 osteotomies to correct interphalangeal hallux valgus, the aim of this study was to test the efficacy of a percutaneous approach for this correction.
Methods: 3 open and 12 percutaneous F2 osteotomies in 15 cadaver feet were performed. Interphalangeal (IPH), F2 asymmetry (AF2) and joint deviation (JD) angles were measured on radiographs. The operated great toes were anatomically analyzed looking for possible lesions to surrounding tissues.
Results: Mean IPH decreased from 10.7° to 2.9°, AF2 from 7.8° to 1°, and JD from 1.4° to 0.5°. Damage to the hallux extensor tendon was detected in 1 foot and a nail bed lesion was detected in 1 case, both operated percutaneously.
Conclusions: F2 Valgus deformity can be corrected using open or percutaneous osteotomy. The authors consider the open correction worthwhile because percutaneous techniques may damage surrounding tissues and the incision length difference is minor.
Level of clinical evidence: 3.

1. Introduction

Interphalangeal (IP) hallux valgus is a true clinical problem that can be due to one or more of 4 causes: distal phalanx (F2) longitudinal axis lateral deviation, morphological anomalies of the phalangeal epiphysis, increased distal articular set angle (DASA), and/or proximal phalanx longitudinal axis lateral deviation.

Despite being frequently seen in daily practice, interphalangeal hallux valgus is a deformity that has not been fully addressed. The literature lacks any studies reporting F2 osteotomies as a treatment for this deformity. Barnett [1] and Sorto et al. [2] studied the hallux IP deviation and showed there is a true clinical reality waiting to be studied in this area. They proposed three angles to quantify the deformity and locate the key anatomical areas of the deformity. However, they did not make any suggestions regarding a possible surgical F2 correction. Nevertheless, several studies on proximal phalanx osteotomies and the possible etiology of the F2 deformity have been carried out [1–3].

Whatever the cause, the fact remains that IP valgus is a problem that may be susceptible to surgical correction. Our clinical experience suggests that this IP deviation can cause painful irritation to the medial side of the toe due to contact with the shoe, and because the first and second toe overlap, leading to a variety of painful problems usually invloving the 2nd toe. This problem can be easily corrected by performing an F2 osteotomy with an open technique and this has been reported in a separate manuscript currently under review for publication by the present authors. F2 osteotomies started to be used after encountering patients dissatisfied with their hallux valgus correction because the nail remained facing the 2nd toe despite excellent correction of the first metatarsal bone and the proximal phalanx.

This experience led us to evaluate the potential indications and benefits of percutaneous techniques to achieve the same results using a less invasive approach. Percutaneous foot surgery uses small incisions, causing minimal trauma to the surrounding tissue because it does not directly expose all the surgical planes. Nonetheless, radiological control is required to guide the procedure. Minimally invasive techniques started being applied in 1945 when Polokoff [4] used small file to polish small exostoses. These techniques were later incorporated by other foot surgeons such as Probber and Weinstock [5], who promoted the use of minimally invasive procedures that have proved highly effective in foot surgery [6–8].

Foot surgery complications are frequently associated with soft tissue [9–12] and bone healing alterations [10,13–15]. Percutaneous surgery is often less susceptible to these complications.

No published treatment algorithms that include distal phalanx percutaneous osteotomies was found in the literature. The goal of this study is to evaluate the feasibility and potential complications of F2

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https://doi.org/10.1016/j.foot.2018.12.001
Received 17 June 2018; Received in revised form 25 November 2018; Accepted 1 December 2018

percutaneous corrective osteotomies.

2. Material and methods

After planning the corrective F2 osteotomy on sawbone feet, it was performed on 15 cadaveric feet to assess possible complications that might arise. An open technique was used in 2 feet and a percutaneous technique in 13 feet.

Image intensifier fluoroscopy was used because it requires lower intensity radiation and has an articulated arm allowing movement to place it in the desired position. The trigger is activated with a pedal, leaving the hands free. The tube is a cold anode that uses currents ranging between 20 and 160 μA.

2.1. Open technique

A 1.5 cm longitudinal incision was made on the tibial side of the second phalanx, centered somewhat ahead of the IP joint, reaching the IP fold. A careful detachment of the tissue and the capsule was performed to reach the bone and periosteum of the area where the osteotomy was to be performed. Hohman spacers were used to improve direct visualization of the area. Using fine motorized chisels an incomplete osteotomy wedge based on the tibial side was performed near the proximal metaphysis of the distal phalanx and was completed with manual osteoclasia. The proximal area of the osteotomy was performed parallel to the F2 articular surface. The osteotomy base length depended on the degree of correction desired. The peroneal side periosteum and superficial tissues remained intact to prevent inadequate deviations. Finally, the osteotomy was fixed with a Kirschner wire but can also be fixed with a staple. Usually the skin is then closed and a corrective bandage is used to help consolidation in the desired position. Postoperative ambulation is allowed from the beginning, using a compression bandage and an orthopedic shoe that protects the forefoot during the boost phase and does not compress the fingers. Throughout the course of 6 weeks the use of regular shoes is progressively permitted.

2.2. Percutaneous technique

A 0.5 to 1 cm longitudinal incision was made on the tibial and slightly plantar side of the metaphysis at the distal phalanx, just ahead of the proximal IP joint and the nail bed fold (Fig. 1). The scalpel is deepened until it reaches the bone, and DPR scrapes (Fig. 2) are used to detach the periosteum where the osteotomy is subsequently performed with an osteotomy burrs at 4000 and 6000 rpm (Fig. 3) on the metaphases immediately distal to the base of the phalanx. Care should be taken with the burrs in order to avoid skin damage. Moderate pressure is applied with an oscillating movement. The burrs tend to move from the designated area. To prevent this, firm pressure should be applied. Once a notch is made we can outline the osteotomy, and gently complete it. Once the osteotomy is finished, pressure is applied to extract the resulting bone paste. The subsequent steps are the same as in the open procedure.

An X-ray analysis was performed to record the correction of the interphalangeal angle (IPH), the F2 asymmetry angle (AF2), the F1 obliquity angle (AF1) and joint deviation, as defined by Sorto et al. [2], measured by the same examiner on anteroposterior radiographs according to standard guidelines.

3. Results

Of the 15 feet, 12 belonged to male, and 3 to female cadavers. The mean age of these patients was 59 years (ranged from 43 to 76).

The F2 percutaneous osteotomy procedure decreased the mean IPH from 10.7° to 2.9°, the mean AF2 from 7.8° to 1°, and the mean joint deviation from 1.4° to 0.5° (Table 1). The 1.5° AF1 did not change because this technique does not alter it.

The incision size was 0.5 cm in the percutaneous surgery and 1.5 cm in the open surgery.

There was no apparent damage to neighboring tissue whenever an open osteotomy was used. The first percutaneous attempt caused a partial tendon lesion of the hallux extensor due to a dorsal displacement of the burrs; and the second attempt caused damage to the nail bed (Fig. 4). It is difficult to accurately assess the potential clinical impact of these damages. These lesions were assessed by dissecting the operated foot. The remaining eleven percutaneous feet had no lesions.

4. Discussion

The IP valgus is a problem that has not been addressed and is therefore not usually included in foot deformity treatment algorithms. After analyzing the problem and possible surgical treatments for the IP deformity, a varus osteotomy of the distal phalanx using an open technique was developed. The aim of this study was to test the efficacy and feasibility of performing this osteotomy percutaneously using a smaller incision.

A well-designed surgical technique can be easily introduced in the general practice avoiding undesired surprises. This is why we decided to perform the surgery in cadaver feet prior to including it in our surgical protocols. The same 0.5 cm incision can be used to simultaneously perform the percutaneous osteotomy and the resection of exostoses located in the distal phalanx and that can be painful [17].

Modern surgery tends to use increasingly minimally invasive percutaneous techniques which solve a variety of problems with a presumably quicker and painless recovery.

After performing the distal osteotomy, the AF2 can be corrected almost entirely and therefore so can the IPA (Fig. 5). However, care must be taken into account as the results are not definite since it is not possible to observe bone healing in cadaver, and the influence of soft tissue cannot be clearly analyzed. Furthermore, it is not possible to observe clinical repercussions of the surgical technique, such as IP mobility loss, lesions of the matrix or nail bed that affect its growth after the surgery or tendon damage [16]. In our experience, percutaneous surgery allows direct correction with good results and slight risk of damaging the nail bed and the tendon structures. Therefore, it can be considered as a good surgical alternative for IP hallux valgus correction

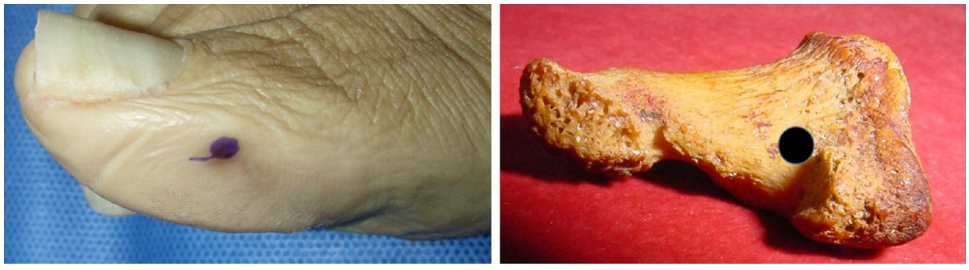

Fig. 1. Exact area where the incision is made to perform the osteotomy (dot).

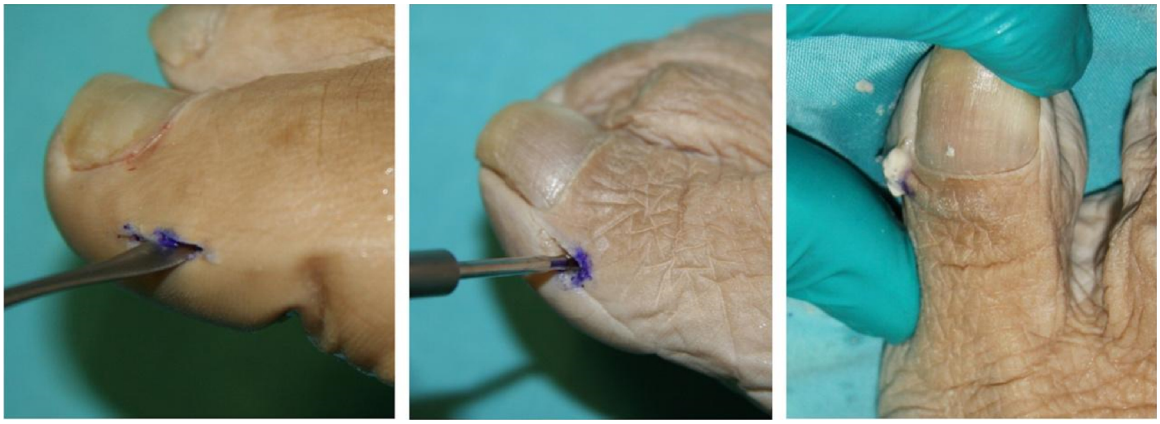

Fig. 2. Periosteum detachment (left) and drilling (middle); bone paste extraction when pressure is applied to achieve manual correction and osteoclasia (right).

and could tack on the hallux valgus treatment algorithm when and F2 deviation needs to be addressed alone or amongst other foot deformities.

Regarding the incision size (0.5 cm in the percutaneous surgery versus 1.5 cm in the open surgery), this difference is irrelevant considering that scars are barely noticeable in the place where it lies.

Our research is not without limitations; preserving feet in formaldehyde causes changes in the structures and behavior of tissues compared with normal practice. Moreover, it is not possible to see the final result after bone consolidation or possible complications that can arise at that point. The specimens were limited, however the main focus of this study is not the efficacy of the osteotomy itself, but of the percutaneous technique. Therefore, the number of specimens is sufficient to show that the percutaneous technique can damage the hallux extensor tendon nail bed lesions.

The percutaneous technique is being used on some of our patients with good results so far. The results in vivo will be discussed in future studies when enough patients have been operated on using this approach.

5. Conclusions

A corrective osteotomy of F2 alone or associated with other osteotomies used in hallux valgus correction can be indicated to correct the IP deformities with lateral deviation of F2 longitudinal axis. Therefore, our technique could be included in forefoot treatment algorithms to address the IP hallux valgus which have not been solved fully with the present techniques, reducing patient dissatisfaction to this effect.

This correction can be done either using an open or a percutaneous technique with good results in both cases, causing little damage to the

Table 1
Changes in the mean angles measured on anteroposterior X-ray views.

	Preoperative	Postoperative	Correction
Interphalangeal angle (IPH)	10.7°	2.9°	7,8
Asymmetry angle of F2 (AF2)	7.8°	1°	6,8
Obliquity angle of F1 (AF1)	1,5°	1,5°	0
Joint deviation angle	1,4°	0,5°	0,9

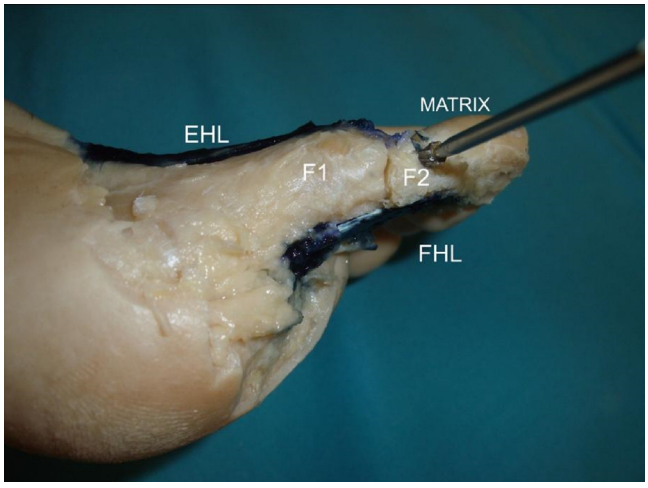

Fig. 4. Dorsal displacement of the burr can injure the tendon of the hallux extensor or the nail matrix (F1: Proximal phalanx; F2: Distal phalanx; EHL: Extensor hallucis longus; FHL: Flexor hallucis longus).

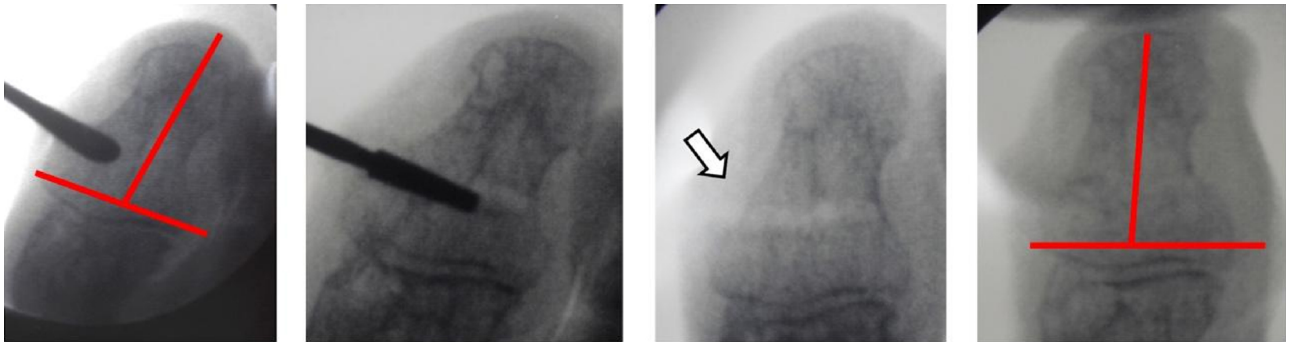

Fig. 3. Image intensifier fluoroscopy view of the percutaneous incomplete osteotomy (arrow). The preoperative AF2 was 12° (image to the left) and was corrected to 2° after surgery (image on the right).

Fig. 5. Preoperative (left) and postoperative (right) X-ray image of an F2 osteotomy. A great angular correction and correction toe position can be observed from the preoperative position (dotted line) to the postoperative correction (continuous line).

surrounding tissues. It is worthwhile to highlight that there are structures (the hallux extensor tendon and the nail bed) at risk with the percutaneous procedure. Owing to the small difference in the incision length required for either technique and the potential risk of lesion with percutaneous approach, it seems that the open technique would be safer.

6. Brief summary

- Interphalangeal (IP) hallux valgus can be corrected by doing a distal phalanx osteotomy.
- The distal phalanx osteotomy can be done using an open or a percutaneous approach
- The open approach seems to have fewer chances of damaging the nail bed and the hallux extensor tendon

Financial disclosure

None reported.

Conflict of interest

None reported.

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