Foot and Ankle Surgery xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Foot and Ankle Surgery

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

Use of a percutaneous osteotomy with plate fixation in hallux valgus correction

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ARTICLE INFO

Article history:
Received 6 February 2017
Received in revised form 30 August 2017
Accepted 8 September 2017
Available online xxx

Keywords:
Hallux valgus
Distal metatarsal osteotomy
percutaneous
Intramedullar plate
Minimally invasive

ABSTRACT

Background: With hundreds of operative methods described for correction of hallux valgus we can state that the ideal surgical treatment is still controversial. The Bösch technique has been used as a percutaneous way of correcting hallux valgus deformities with the use of a pin fixation. The aim of this study is to evaluate a new method of fixation by using a percutaneous locking plate.
Methods: Between June 2013 and January 2015, 24 consecutive percutaneous subcapital osteotomies of the first metatarsal bone were performed for the treatment of painful hallux valgus deformities in 24 patients. Additional surgical procedures included DMMO's (Distal Metatarsal Minimally-Invasive Osteotomies) in 12 of the operated feet (44.44%); minor digits were corrected in 7 cases (25.9%). An Akin procedure was performed in 81% of cases and all cases underwent an adductor hallucis tenotomy. All patients were clinically assessed using the AOFAS score. Radiographic measures included the preoperative and postoperative values of the Hallux Valgus Angle (HVA), Intermetatarsal Angle (IMA), and the Distal Metatarsal Articular Angle (DMAA).
Results: The mean correction achieved improved for AHV from 36.57 ± 7.1 to $12.22 \pm 8.69°$, for IMA from 13.8 ± 1.59 to 7.08 ± 2.72 and for DMAA from 13.98 ± 7.38 to 6.07 ± 4.99. Clinically, scores on the AOFAS scale improved from a 45.8 ± 9.6 to 91.29 ± 9.8.
Although healing of the osteotomies was observed radiographically within 6 to 12 weeks, two cases (8.3%) exhibited delayed healing. There were no cases of nonunion. There were no superficial or deep infections or wound healing problems. Plate had to be removed in 3 cases (12.5%).
Conclusion: This technique modification is an acceptable procedure to correct hallux valgus in patients with a moderate level of deformity.
Level of evidence: Level IV. Case series.

1. Introduction

Hundreds of techniques have been described for surgical correction of hallux valgus [1,2]. Starting in the 1990's [3,4], the so-called percutaneous techniques gained great popularity in foot surgery. Initially, there were two different groups, each with its own techniques and philosophy. There were the techniques popularized by de Prado et al. [4] in Europe, which advocates the performance of distal first metatarsal Reverdin-Isham-type osteotomies and a percutaneous release of the Abductor Hallucis tendon alongside a percutaneous Akin osteotomy. On the other, Bösch's percutaneous adaptation [5] of the technique originally described by Kramer [6], consisting of a distal subcapital osteotomy of the first metatarsal where a K-wire is used to displace the metatarsal laterally and fix the osteotomy. With the passage of time, surgeons came up with several variations on these techniques in order to address the limitations and complications they encountered [7–12].

The Reverdin-Isham osteotomy is not recommended for cases of hallux valgus where the intermetatarsal angle (IMA) is greater than 15° [13,14] requiring the addition of a proximal osteotomy for greater angle correction [15]. Also, the bunionectomy that is part of this procedure may at times result in the release of bone debris into the joint space which, coupled with the postoperative immobilization required to hold the osteotomies apposed, could impair the range of motion of the metatarsophalangeal joint [4,13,14].

Bösch's technique had a broader range of indications and has been used for severe cases of hallux valgus, where the IMA was greater than 20° [3,6,16]. Nonetheless, use of this technique

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http://dx.doi.org/10.1016/j.fas.2017.09.002
1268-7731/

involves a distal first metatarsal osteotomy, which may result in a displacement of up to nearly 100% of the diaphyseal width, making the osteotomy highly unstable. Taking into consideration that fixation with a K-wire is inherently precarious, this technique tends to be associated to a higher complication rate [16–18].

On the other hand, the use of the K-wire is associated with a series of disadvantages such as transarticular fixation for a period of 6 weeks and rotational and dorsoplantar instability [16–18], which could lead to an elevation of the metatarsal head and the development of transfer metatarsalgia.

This article describes a modification of Bösch's technique that involves replacing the K-wire by a V-TEK plate (Zimmer, Inc., Warsaw, USA), which allows a more rigid fixation of the osteotomy with greater rotational and dorsoplantar stability preserving the advantages of a percutaneous operative procedure. As the technique reported herein does not utilize transarticular fixation, it permits immediate mobilization of the metatarsal joint. The aim of this article is to present the initial results of this technique relative to angle correction, clinical outcomes and complications and to compare it with the results of other techniques previously described in the literature.

2. Materials and methods

Between June 2013 and January 2015, 24 feet were operated in 24 female patients, all of them in the same hospital and by the same surgeon. Final follow-up was 24 months. No patients were lost during follow-up. The average age at the time of surgery was 59 (range 48–71) years. Postoperative evolution was monitored clinically and radiographically at 6 weeks, 3 months, 6 months 1 year and 2 years following surgery (Fig. 1).

Pre- and postoperative AOFAS (American Orthopaedic Foot and Ankle Society) scores were recorded and the radiographic correction obtained was calculated by measuring the values of the IMA, the HVA (Hallux Valgus Angle) and the DMAA (Distal Metatarsal Articular Angle) on weightbearing radiographs.

Preoperative IMA values ranged from 12 to 17.3°; the HVA ranged from 27 to 47°. Subjects with previous surgeries and those where the plate was placed using an open technique were excluded from the study. Surgery was only indicated in patients who experienced pain as well as significant limitations in their ADLs or their recreational activities. Feet with an AIM under 12° were operated by using a percutaneous Reverdin–Isham osteotomy [19] and above 16° double or triple percutaneous osteotomies were performed [15].

Additional operative maneuvers included DMMO's (Distal Metatarsal Minimally-Invasive Osteotomies) in 12 of the operated feet (44.44%); minor digits were corrected in 7 cases (25.9%). An Akin procedure was performed in 81% of cases and all cases underwent an adductor hallucis tenotomy, performed in a percutaneous way as described by De Prado et al. [4].

DMMOs were indicated when a metatarsalgia in the preoperative evaluation was detected. Although isolated correction of the hallux valgus can lead to an improvement of the metatarsalgia [20], DMMOs are easy and fast to perform with very good postoperative results and can prevent against transfer metatarsalgia in case of elevation of the first metatarsal osteotomy [15,21].

A percutaneous Akin osteotomy adds a few degrees of HVA correction and prevents against undercorrection of the Hallux valgus. Unless there is obvious intrinsic deformity of the proximal phalanx, we consider the Akin osteotomy after performing the metatarsal correction. If the toe is still deviated (provided the metatarsal correction was adequate), then we perform the Akin. Percutaneous Adductor hallucis tenotomy is performed in all cases as an ancillary procedure in order to neutralize a deforming force and prevent undercorrection or recurrence of the deformity.

The statistical analysis was performed using version 22 of the SPSS software package (IBM, Armonk, USA). A descriptive analysis

Fig. 1. Example case showing pre-op (left) and post-op (right) radiographs at two years' follow-up.

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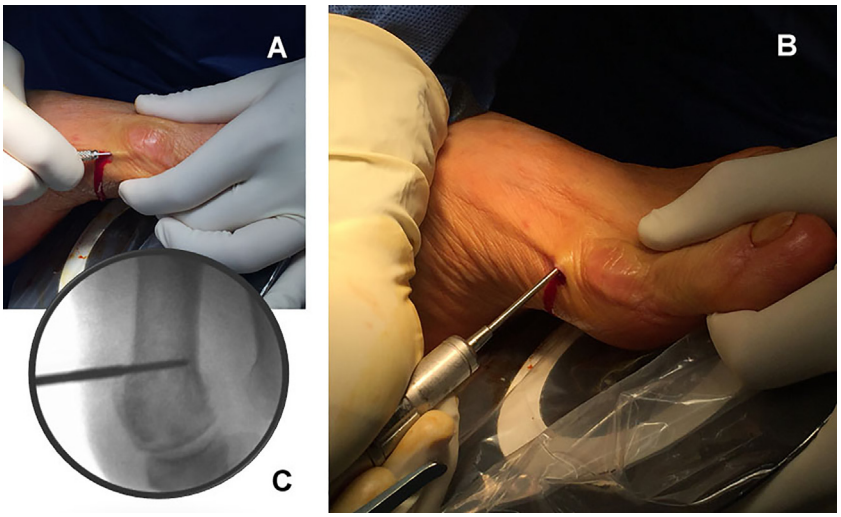

Fig. 2. Percutaneous subcapital osteotomy. 2A: Incision centered over the metatarsal, just proximal to the bunion. 2B: Osteotomy using a long #44 Shannon burr. 2C: Fluoroscopic view.

was obtained and the Kolmogorov–Smirnov test for normality was carried out. In case of doubt, individual histograms were analyzed to check for kurtosis and parametric mean comparisons were made in cases where the histogram approached normal distribution. In these cases, Student's t test was used to compare two related variables. The Wilcoxon Signed Rank Test was used for non-parametric data. Analysis of the correlation between the two variables was conducted using Pearson's correlation coefficient in cases of normal distribution. The p value was always lower than 0.05.

2.1. Surgical technique

The patient is placed supine on the operating table with both calves hanging from the edge of the table so as to allow optimal use of the mini C-arm, which is indispensable for a percutaneous procedure. In all cases, the anesthetic technique consisted in a popliteal nerve block. All patients were administered a preoperative dose of 2 g cefazolin. Ischemia was not required in any of the procedures.

The initial incision, around 3–5 mm in length, is performed with a #64 Beaver blade placed proximally to the bunion half way between the dorsal and the plantar aspects of the metatarsal. The capsular incision is extended subcutaneously in a distal direction so that the plate can be apposed to the bunion (Fig. 2). A bunionectomy is not performed.

After conducting a dorsal and plantar stripping of the metatarsal head in order to protect the dorsomedial nerve, a linear subcapital osteotomy is carried out from dorsal to plantar with a Shannon 2 × 12 mm burr (CHOC, Montauban, France). This maneuver is completed by fully detaching the distal portion of the osteotomy (the metatarsal head) (Fig. 2). Subsequently, a V-TEK plate (Zimmer, Inc., Warsaw, USA) is introduced through the osteotomy site, shifting the head laterally so that the intramedullary plate remains facing the proximal portion of the head and the skin is in contact with its distal portion (Fig. 3). The distal fragment is easy translated laterally by pressing with the thumb or just letting the plate to displace the osteotomy during the introduction of the plate. Additional maneuvers of rotation or angulation can be performed by pulling or rotating the toe.

Once correct plate positioning is checked under fluoroscopic control, the two proximal screws can be introduced using the positioning jig and two 1 mm-long incisions (Fig. 4).

With the plate fixed proximally, the hallux is subjected to traction so as to create a "mobile window" effect. This allows the surgeon to introduce the distal portion of the plate subcutaneously (Fig. 5), after replacing the external guide by the threaded distal locking screw guide. Once the screw is in place, correct positioning

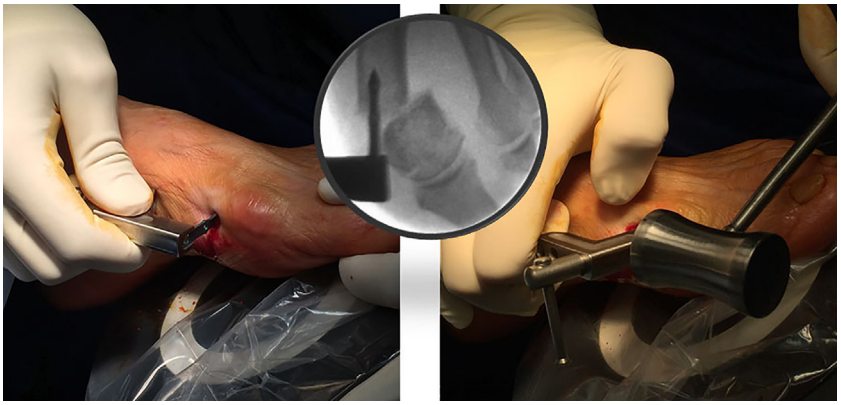

Fig. 3. Insertion of the plate through the skin incision and the osteotomy site.

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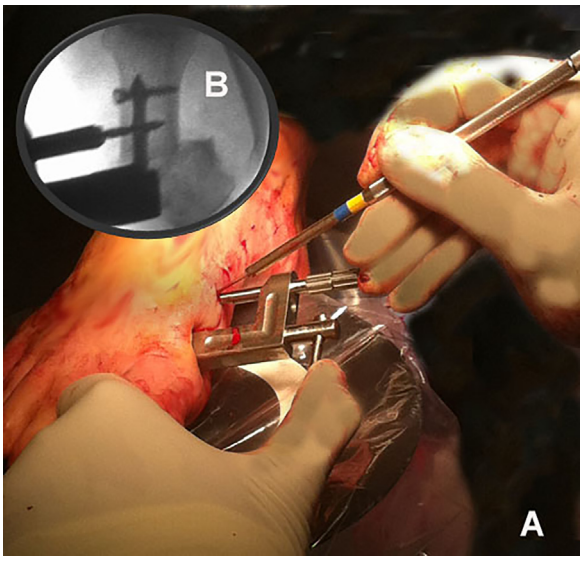

Fig. 4. Fixation to the metatarsal shaft with two proximal percutaneous screws.

of the metatarsal head is checked fluoroscopically on the dorsoplantar and mediolateral planes (in order to prevent elevation of the metatarsal head). The wound is sutured with 3-0 monofilament (Fig. 6).

Depending on the accuracy of the correction achieved, additional surgical procedures may be necessary. These may range from an Akin osteotomy, adductor hallucis tenotomies, DMMO, or corrections of hammertoe or claw toe.

Finally, a functional bandage is applied with hypercorrection of the hallux valgus, which is required to keep the Akin osteotomy aligned if performed, the bandage must be used for 6 weeks and exchanged weekly by the nursing staff.

Weightbearing is allowed from the first day with postoperative forefoot-off-loading shoe. Full weightbearing is allowed at 6 weeks with comfortable footwear.

3. Results

Clinically, scores on the AOFAS scale improved from a 45.8 ± 9.6 preoperatively to 91.29 ± 9.8 postoperatively ($p < 0.0001$). As far as the different radiographic angles are concerned, AHV went from 36.57 ± 7.1 to 12.22 ± 8.69 postoperatively ($p < 0.0001$). AIM

Fig. 5. By applying slight traction to the hallux, the incision is shifted distally thus allowing introduction of the plate in direct contact with the metatarsal head. Given the the distal screw locking properties, it acts as an internal fixator with no need of direct contact to the bone. An eyelid was previously created in the joint capsule.

Fig. 6. Intra-operative fluoroscopic views showing correct placement of the plate and accuracy of the osteotomy (6A). There is no metatarsal head elevation (6B). 6C shows the appearance of the surgical wounds following completion of the procedure.

disminished from 13.8 ± 1.59 to 7.08 ± 2.72 ($p < 0.0001$) and DMAA from 13.98 ± 7.38 to 6.07 ± 4.99 ($p < 0.0001$). Although healing of the osteotomies was observed radiographically within 6–12 weeks, two cases (7.4%) exhibited delayed healing, that resolved in less than 6 months. There were no cases of nonunion. There were no superficial or deep infections or wound healing problems. Sutures were removed within 2–3 weeks from surgery.

HVA $< 15^{\circ}$ was considered normal, HVA values between $15–25^{\circ}$ were observed in 7 patients (26% of cases). However, none of these patients except for one considered these results unsatisfactory. The patient who was dissatisfied complained of pain and, given the presence of arthritic signs on the postoperative X-rays, an arthrodesis was indicated.

It was necessary to remove the plate in 3 cases (11%) because the shoe rubbed against the plate causing patient discomfort. This required a new surgical procedure being able to remove all the implanted hardware using the previous skin incisions in all 3 cases. Symptoms disappeared following explanation. No patient developed transfer metatarsalgia. No avascular necrosis of the metatatarsal head or neuritic symptoms were observed in our series.

4. Discussion

In 1984 Bösch et al. [5] abandoned the Keller Brandes technique he had been using up to then and developed a new technique consisting in a modification of the procedure earlier described by Kramer [6] (which in turn drew on a technique conceived by Hohmann). What Bösch did was adapt Kramer's technique for percutaneous use. He proposed a subcapital osteotomy performed via a corticotomy with a dental bur. Subsequently, a K-wire was driven into the medial pad of the first toe and then introduced intramedullary into the proximal part of the osteotomy site. This maneuver fixed the osteotomy site and shifted the metatarsal head to allow correction of the deformity.

Roukis [22] makes a distinction between percutaneous and minimally invasive surgery. Within the first group, he includes techniques that use incisions shorter than 5 mm and require specific surgical materials (such as Shannon or Wedge burrs) as well as C-arm support to compensate for the surgeon's lack of direct line of vision. In contrast, he considers that in minimally invasive surgery incisions must be within 2 cm long, a variety of surgical instruments can be used (such as micro-saws, retractors, etc.), and fluoroscopy is not required.

Several studies have reported good results with the technique described by Bösch [23–28] which, in spite of performing a distal

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Table 1
Comparison with other studies.

Authors	Year	Patients (feet)	Technique	Follow-up (months)	Maximal AIM operated	IMA improvement in degrees	HVA improvement in degrees	AOFAS postOP	Age
Angthon et al. [36]	2013	30(36)	Bösch	10	Todos	7.1	22.3	95	59
Barragán-Hervella et al. [37]	2008	29(40)	R-Isham	6	<18	–	–	96.62	42
Bauer et al. [13]	2009	168(189)	R-Isham	12	<15	3	14	93	55
Bauer et al. [14]	2010	82(104)	R-Isham	24	<15	3	15	87.5	57
Bösch et al. [3]	2000	64(98)	Bösch	90	<18	3	17	–	49
Bösch et al. [5]	1990	45(64)	Bösch	15	<19	5	17	–	44.1
Brogan et al. [34]	2014	35(45)	Bösch	9.1	todo	7.44	20.1	–	54
Cervi et al. [38]	2014	213	R-Isham	5-29	<18	–	–	90	55
De Prado et al. [4]	2003	64(64)	R-Isham	30	<20	5	24	–	51
Enan et al. [39]	2010	26(40)	Bösch	21	<18	5.4	13.10	91.1	37.8
Faour-Martín et al. [40]	2013	87(115)	Bösch	121	<20	9.5	19.6	89.3	44.7
Gądek y Liszka [10]	2013	54(59)	Bösch	18	14	5.1	19.7	90.7	45.7
Giannini et al. [7]	2013	20(40)	SERI/scarf	84	<20	9.3	14	89	53
Huang et al. [32]	2011	82(125)	Bösch	18	<15.4	4.7	11.2	–	40.8
Iannò et al. [28]	2013	72(85)	Bösch	73	<25	8.1	19.9	87.3	51.7
Kadakia et al. [16]	2007	13(13)	SERI	4.3	<16	3.9	13	–	52
Lin et al. [41]	2009	31(47)	Bösch	6	14.7	6.3	11.8	92.7	40.8
Maffulli et al. [27]	2009	36(36?)	Bösch/ scarf	30	<20	7	10	85	51.5
Magnan et al. [42]	2005	82(118)	Bösch	35	<20	5	17.8	88.2	56.3
Markowski et al. [26]	1991	44(63)	Bösch	16	–	4	17	–	44
Merino- Pérez et al. [43]	2010	50(70)	Bösch	90	<20	7.3	13.7	87.81	57
Pichierri et al. [44]	2014	–(138)	R-Isham	5-15	<18	–	–	91	55
Portaluri et al. [23]	2000	143(182)	Bösch	16	<19	7	16	–	42.8
Radwan y Mansour [31]	2012	64(53)	Bösch/ chevr.	21	<20	4.8	14.4	90.2	32.7
Vernois y Redfern [11]	2013	341(100)	MICA	12–36	<22.5	9	26.4	–	–
Roth et al. [25]	1996	(88)	Bösch/ Kram.	15.6	<20	17.25	4.33	–	49
Sanna y Ruiu [45]	2005	83(90)	Bösch	30.5	<23	5.9	19.5	–	58.9
Scala y Vendettuoli [9]	2013	126(146)	Bösch	29	<22	9.6	27.8	85.3	52.6
Sié et al. [46]	2013	4(6)	Bösch	10	<20	8.3	17.9	–	37
Steinböck y Leder [47]	1988	46(72)	Akin-New	12	<12	0	11	–	50
Sun et al. [48]	2010	79(150)	Bösch	90	¿?	4.95	20.97	84.2	47
Valles-Figueroa et al. [49]	2010	40(58)	Bösch	6	<20	7.5	13.1	80.9	49
Weinberger et al. [50]	1991	204(301)	Hohmann perc.	–	<23	–	18.5	–	48.6
Zanolli de Solminhiac y Fernández Comber [51]	2011	52(90)	P.B.O.	11	9–22	8.1	–	–	55.4
This series	2017	24(24)	Bösch	24	<17	1.58	24.35	91.3	59

osteotomy, has been applied even in the case of severe deformities. According to the literature, the technique has been used both percutaneously [3,29] and as a minimally invasive procedure.

In 2009, Mafulli et al. [27] carried out a level of evidence II study where he compared the results of 36 feet operated with a scarf osteotomy with those of the same number of feet operated with Bösch's technique. He found out that operative time and hospital stay were shorter with the percutaneous technique, although the results of both were comparable with respect to AOFAS score and angle measurements. In 5 patients operated with the scarf osteotomy, screw removal was necessary because of a protuberance on the dorsum of the toe and skin irritation resulting from the shoe rubbing against the skin. In 1996 Roth et al. [25] compared the Kramer to the Bösch technique and obtained similar results, albeit with a non-significant increase in perioperative complications in the percutaneous technique, attributed to the learning curve. Giannini et al. [30] operated 20 patients with bilateral hallux valgus using the scarf osteotomy in one foot and a technique he calls SERI (Simple, Effective, Rapid, Inexpensive) in the contralateral foot, which avoids the use of a C-arm. Results of the two groups were very similar although incisions were shorter with SERI, operation time was shorter and the fixation method much less costly. In 2012, Radwan and Mansour [31] compared Bösch's technique with a distal chevron osteotomy. The cosmetic results of the percutaneous procedure were better than those of the chevron procedure.

Nonetheless, Bösch's technique is not exempt from controversy, particularly as a consequence of the results published by Kadakia et al. [16], who reported an unacceptable complication rate. This high number of complications occurred in spite of the fact that the author used a modified technique that involved a second K-wire that transfixed the osteotomy. In his series of 13 consecutive patients, they had 9 cases (69%) of metatarsal head elevation, one case of osteonecrosis and one of nonunion. The deformity recurred in 38% of cases (5 patients). The author concludes that the Bösch technique cannot be recommended for hallux valgus correction as there are alternative procedures that afford superior results. Iannò et al. [28] described a medium-term complication rate of 29.4% in a series of 72 patients (85 feet) with a mean follow-up of 73.3 ± 38 months. Scala and Vendetuoli [9] claim that postoperative immobilization with a K-wire alters the metabolism of articular cartilage thus causing damage to the tissue. In a cohort of 82 patients (125 feet), Huang et al. [32] advise against using the technique given the high rates of HVA hypercorrection observed (63.9%) in patients with a preoperative HVA $> 30°$. For that reason, they recommend open surgery with a first metatarsal osteotomy plus capsulorrhaphy.

Several modifications to the technique have been proposed with a view to address the various complications arising particularly from precarious fixation. Firstly, a single K-wire is not able to provide adequate rotational or dorsoplantar stability, which may induce an elevation of the metatarsal head [16,17].

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Moreover, placement of the wire to fix the metatarsophalangeal joint could result in potential joint stiffness [16–18].

In 2012, Scala and Vendettuoli [9] proposed a modification consisting of cutting and bending the distal end of the K-wire to then drive it into the osteotomized metatarsal head thus achieving joint stability without immobilization. However, this technique requires a longer incision so the procedure cannot be considered to be percutaneous.

In 2013, Gadek and Liszka [10] presented a new modification that included a step cut osteotomy of the first metatarsal similar to that used by Mitchell et al. [33], which displaces the metatarsal head laterally to correct the deformity.

Another variation on the same theme was introduced by Brogan et al. [34] and Vernois and Redfern [11], who carry out a percutaneous chevron procedure and use a K-wire but only to displace the osteotomy as fixation of the osteotomy is achieved with a cannulated screw.

The present article proposes an innovative modification that enhances fixation of the osteotomy site with a locking plate. In this way, the advantages of percutaneous surgery (shorter incisions, less soft tissue damage, shorter operative time, etc.) are combined with those inherent in a more stable fixation that does not interfere with joint motion.

The use of plates and other similar devices was reported by Bösch himself [5], who in the presence of very severe deformities used an unlocked intramedullary plate placed proximally to the osteotomy site and a locked plate placed medially to the metatarsal head. This procedure was performed through an open incision. Stoffella [35] designed a device with an expansive intramedullary fork in its distal portion, which is implanted through a standard incision. In 2014, Palmanovich and Myerson [17] presented the Orthohelix Mini MaxLock Extreme ISO plate (Wright Medical Technology Arlington, TN, USA) with screws on its proximal portion, which is inserted with fluoroscopic guidance through a 3 cm-long medial incision. Unfortunately, the results of the procedure have not been published.

The V-TEK plate (Zimmer, Inc., Warsaw, USA) designed by Vitek and Hlozek [18] is implanted following the original technique using an open approach, with an incision similar to the one used for an open scarf or chevron procedure. The results of the first 20 feet operated with this system, presented in 2008, were satisfactory [18]. We decided to use of this plate percutaneously as its design allows implantation through a millimetric incision. There are to date no published reports on the use of the V-TEK plate in the fixation of osteotomies in percutaneous hallux valgus surgery.

The results obtained are both clinically (AOFAS score) and radiographically (IMA, HVA and DMAA measurements) comparable to those obtained by other authors using either percutaneous or open procedures (chevron, scarf and other osteotomies), although direct comparisons are difficult given, among other things, the high variability exhibited by the degrees of deformity reported in the different studies (Table 1). Almost the totality of the operated hallux valgus in our study can be classified under moderate Hallux valgus deformities according to Mann and Coughlin classification. Due to our satisfactory preliminary results, we are now expanding the indications to more severe deformities. A possible disadvantage is the cost of the place (around 390€), that is more expensive than of two cannulated screws and a varization staple in a scarf/Akin procedure (260€).

The present retrospective case series is subject to the limitations as the number of cases is small and the maximum follow-up of only two years. This may induce the risk of overlooking complications such as transfer metatarsalgia which tend to manifest themselves in the medium- to long-term. A comparison between the two methods of fixation should be done in order to compare the advantages for this new method of fixation.

However, our initial results would seem to warrant a certain measure of optimism regarding the advantages that this modification might procure. We believe that indications could well be expanded to severe deformities, although a longer follow-up and a larger number of cases are needed to draw definite conclusions.

5. Conclusion

The results obtained related to angle correction, clinical outcomes and described postoperative complications in a follow-up within two years are comparable to other more established techniques. Further research should be undertaken to clinically compare other surgical options and evaluate the results in a longer term.

Conflict of interest

I declare no conflicts of interest.

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