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Minimally invasive distal first metatarsal osteotomy can be an option for recurrent hallux valgus

Bruno Magnan*, Stefano Negri, Tommaso Maluta, Carlo Dall'Oca, Elena Samaila

Department of Orthopaedics and Trauma Surgery, University of Verona, Azienda Ospedaliera Universitaria Integrata di Verona, Italy

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ABSTRACT

Background: Recurrence rate of surgical treatment of hallux valgus ranges in the literature from 2.7% to 16%, regardless of used procedure. In this study, long-term results of a minimally invasive distal osteotomy of the first metatarsal bone for treatment of recurrent hallux valgus are described.
Methods: 32 consecutive percutaneous distal osteotomies of the first metatarsal were performed in 26 patients for treatment of recurrent hallux valgus. Primary surgery had been soft tissue procedures in 8 cases (25%), first metatarsal or phalangeal osteotomies in 19 cases (59.4%) and Keller procedures in 5 cases (15.6%).
Results: Patients were assessed with a mean follow-up of 9.8 ± 4.3 years. All patients reported the disappearance or reduction of the pain. The mean overall AOFAS score improved from 46.9 ± 17.8 points to 85.2 ± 14.9 at final follow-up. The mean hallux valgus angle decreased from 26.1 ± 9.1 to $9.7 \pm 5.4°$, the intermetatarsal angle decreased from 11.5 ± 4.5 to $6.7 \pm 4.0°$. No major complications were recorded with a re-recurrence rate of 3.1% (1 case).
Conclusions: Percutaneous distal osteotomy of the first metatarsal can be a reliable and safe surgical option in the recurrent hallux valgus with low complication rate and the advantages of a minimally invasive surgery.
Levels of evidence: : IV, Retrospective Case Series.

1. Introduction

Hallux valgus (HV) is a multifactorial deformity affecting the forefoot often resulting in morbidity and decreased quality of life. It is characterized by lateral deviation of the great toe and varus of the first metatarsal often leading to sub-dislocation of the first metatarsophalangeal joint (MTPJ1). The etiology is varied, but females are more commonly affected because high genetic predisposition and other risks by use of constricting footwear [1]. In the literature, many surgical procedures have been described, but complication rates following HV surgery have been reported to be as high as 50% [2], including hallux varus, MTPJ1 instability, infection, recurrent deformity, and avascular necrosis (AVN) of the first metatarsal head. In particular, recurrence rate varies from 2.7% to 16% [3–5]. Recurrence of hallux valgus deformity after surgical correction is multifactorial and one of the most common causes is an incomplete initial correction. Furthermore, anatomical and biomechanical factors can predispose a patient to a recurrent deformity. Unfortunately, despite careful analysis, the cause of recurrence may be unknown.

Surgical options described for recurrences' treatment include mainly techniques such as metatarsophalangeal or cuneometatarsal fusions, resection arthroplasties and metatarsal osteotomies [6–12], but this revision surgery is often burdened by a high rate of complications (Table 1), which can reach 50% [13–16] up to 80% of cases especially following a salvage Keller arthroplasty [17,18].

A common postoperative complication of recurrent HV surgery, even with "joint sparing" procedures, is joint stiffness or arthrofibrosis whose preventive care is difficult to achieve [19]. More frequently, delayed-, mal- and non-unions, transfer metatarsalgia, re-recurrent deformity, superficial and deep infection are reported [4]. Another complication is hallux varus, most commonly occurring after a proximal metatarsal osteotomy although many patients are asymptomatic and do not require treatment, particularly if the hallux varus measures less than 10° [12,13,15]. Although uncommon, AVN of the first metatarsal head following recurrent hallux valgus surgery can lead to loss of function of the MTPJ1 and being caused by a disruption of the blood supply to the metatarsal head [20].

* Corresponding author at: Department of Orthopaedics and Trauma Surgery, University of Verona, Azienda Ospedaliera Universitaria Integrata di Verona, P.le A. Stefani 1, 37126 Verona, Italy.
E-mail address: bruno.magnan@univr.it (B. Magnan).

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Table 1
Summary of literature's results of surgical treatment of recurrent hallux valgus. Number of cases, followup duration, clinical results and complication rates have been highlighted.

Study	Year	Procedure	Cases at FU	FU	Clinical mean score	Complications
Rose et al. [7]	2014	Scarf osteotomy	36	3.9 years (1–5)	AOFAS 83.4 (52–100)	–
Ellington et al. [8]	2011	Lapidus	25	2.6 years (1–5)	AOFAS 82.8 (59–100)	5 (20%) discomfort related to implants 1 (4%) nonunion 1 (4%) recurrent deformity
Bock et al. [13]	2010	Scarf osteotomy	39	3.5 years (2–7.4)	AOFAS 89.8 (68–100)	7 (18%) metatarsalgia 1 (2.6%) asymptomatic recurrence 3 (7.7%) overcorrection 3 (7.7%) intermittent paresthesias 5 (12.8%) painful hardware
Vienne et al. [9]	2006	MTP1 fusion	22	2.8 years (2–4)	AOFAS 85 (73–90)	2 (9.1%) non-union 2 (9.1%) painful implant prominence 1 (4.5%) implant loosening
Grimes et al. [10]	2006	MTP1 fusion	33	8 years (1–22)	AOFAS 73 (55–90)	4 (12.1%) nonunions 2 (6.1%) ingrown nails
Coetzee et al. [11]	2003	Modified Lapidus	26	1.8 years (6 months–3 years)	AOFAS 87.9	3 (11.5%) nonunions 2 (7.7%) superficial wound infections
Machacek et al. [17]	2004	MTP1 fusion	29	3 years (2–6.3)	AOFAS modified* 76 (50–90)	3 (10.3%) persistent metatarsalgia 1 (3.5%) new onset metatarsalgia 3 (10.3%) malunions, 3 (10.3%) nonunions, 2 (6.9%) superficial wound infections, 1 (3.4%) deep infection, 1 (3.4%) complex regional pain syndrome, 4 (13.8%) painful hardware
Machacek et al. [17]	2004	Re-do Keller or tendon lengthening	21	6.2 years (2.3–11)	AOFAS 51 (15–80)	8 (38%) cock-up toe deformity 5 (23.8%) recurrent deformity 5 (23.8%) transfer metatarsalgia 1 (4.8%) deep infection
Rochwerger et al. [12]	2002	Soft tissue procedure with/or not MacBride	35	6.9 years (2–21)	24 (68.5%) Good results 11 (31.5%) Poor results	7 (20%) persistent deformity 2 (5.7%) hypercorrection 1 (2.8%) painful arthrodesis 1 (2.8%) MTFJ incongruence
Rochwerger et al. [12]	2002	MTP1 fusion	29	6.9 years (2–21)	25 (82.7%) Good results 3 (10.3%) Poor results	1 (3.4%) migration of hardware 1 (3.4%) malcorrection 1 (3.4%) instability M1 and M2
Kitaoka et al. [15]	1998	Proximal crescentic osteotomy	15	5 years (2–14)	AOFAS modified** 71.5	3 (27.3%) transfer metatarsalgia 2 (13.3%) recurrent deformity 1 (9.1%) malunion 1 (9.1%) hallux varus 1 (9.1%) nonunion
Kitaoka et al. [18]	1998	MTP1 fusion	9	10 years (3–15)	AOFAS modified** 67.7	3 (33.3%) residual deformity 1 (11.1%) nonunion 1 (11.1%) degenerative arthrosis of IFJ 1 (11.1%) hardware removal 1 (11.1%) cockup toe
Kitaoka et al. [18]	1998	Resection arthroplasty	11	10 years (3–15)	AOFAS modified** 63.7	6 (54.5%) recurrent deformity 3 (27.3%) cockup toe 1 (9.1%) complete limitation of MTPJ plantar flexion
Coughlin et al. [14]	1987	MTP1 fusion	16	2.4 years (2–4)	Pain 1.3 (1–5 scale) Ability to walk 1.6 (1–5 scale)	1 (6,3%) persistent metatarsalgia 10 (62.5%) persistent IFJ ROM reduction
Jarde et al. [16]	2001	MTP1 fusion	32	6.6 years (5–19 years)	AOFAS (not explicitated the value of score)	4 (12.5%) persistent metatarsalgia 4 (12.5%) algodystrophy 3 (9.4%) nonunion 4 (12.5%) interphalangeal osteoarthritis

AOFAS American Foot and Ankle Society.
* Scale was modified to a maximum score of 90 by removing 10 points assigned to the range of motion of the first meta-tarsophalangeal joint.
** Scale was modified to a maximum score of 75 point. IFJ, interphalangeal joint; MTPJ, meta-tarsophalangeal joint; ROM, range of motion.

Therefore, orthopedic community nowadays is searching for alternative MIS approaches also for revision surgery, in order to lower the rate of complications related to extended surgical exposures, to reduce operating times with comparable functional and cosmetic results to those reported with traditional procedures. In the literature, several MIS procedures have been proposed for surgical treatment of primary HV, even with some differences among them; by the same or very similar MIS or percutaneous approaches, indeed, different surgical steps can be performed: proximal or distal first metatarsal osteotomies with or without lateral displacement of the capital fragment, distal medial bony wedge subtraction, minimal or no soft tissue releases, combined or not with a proximal phalanx osteotomy [21–25]. In general, MIS procedures have been indicated for primary mild-to-moderate HV, even if some authors have preliminarily reported MIS revision surgery in selected cases

[26]. The question is if this kind of techniques could be successfully suitable also for a recurrent HV, in consideration of the severity of these cases, in presence very often of joint stiffness or sub-dislocation, scar adhesions, bone loss at the metatarsal head or absence of the proximal phalanx joint surface. For this purpose, attention has turned to those MIS techniques commonly used for primary HV surgery, able to address most of the components of a recurrent deformity, such as a severe first metatarsal varus, sesamoids' dislocation and joint incongruence despite a soft tissues stiffness due to residual scar. Among these, the percutaneous distal osteotomy of the first metatarsal (PDO) as proposed by Magnan et al. in 1997, as a modification of Bosch technique, could appear one of the most appropriate MIS procedures in order to address most of the features of a recurrent deformity [24,25,27–29]; this because its linear monoplanar distal osteotomy of the first metatarsal bone allows a multiplanar correction, when needed, by a great amount of lateral displacement of the capital fragment, a lateral–medial tilting, a plantarization and rotation on the frontal plane.

The aim of our study was to assess the mid-long term outcomes of the PDO in recurrent HV for the treatment of patients with failure following other procedures.

Fig. 1. Clinical case: 57-year-old woman with HV recurrence after Austin procedure: (A) preoperative anteroposterior weightbearing radiograph, (B) postoperative, (C) 3-months postoperative radiograph, (D) 14 years follow-up radiograph and (E) follow-up clinical appearance.

2. Materials and methods

2.1. Subjects-assessment

From January 1997 to December 2010, 35 consecutive PDO of the first metatarsal were performed for the treatment of recurrent HV in 29 patients. At follow-up, 2 patients were died and there was 1 patient lost to follow-up. These three patients were excluded from the study. There were 25 females and 1 man for 32 procedures (6 bilateral) available for a retrospective evaluation with an average age at the time of surgery of 54.2 years (range, 33–68). All the subjects have given informed consent and the study has been approved by the institutional review board. Inclusion criteria were painful recurrent HV with a hallux valgus angle (HVA) more than 20° up to 40°, an intermetatarsal angle (IMA) less than 20° and at least 60° of residual MTPJ1 range of motion (ROM), where a lower motion was considered for a fusion. Recurrent HV in rheumatoid arthritis were excluded.

Primary surgery had been soft tissue procedures in 8 cases (2 simple medial capsule complications and six Mc Bride

Fig. 2. Clinical case: 52-year-old woman with bilateral HV recurrence following bilateral Austin osteotomy coupled with Akin procedure: (A) preoperative anteroposterior weightbearing radiograph, (B) preoperative clinical appearance, (C) postoperative, (D) 3 years follow-up radiograph and (E) follow-up clinical appearance. Dislocation of second metatarsophalangeal joint was not treated being asymptomatic at the time of surgery.

procedures), first metatarsal or proximal phalangeal (P1) osteotomies in 19 cases: 4 Austin osteotomies (Fig. 1A), 2 Austin coupled with Akin (Fig. 2A and B), 2 Lamprect–Kramer, 3 proximal osteotomies of the first metatarsal, 1 proximal osteotomy (lateral closing wedge) coupled with Akin, 2 Akin, 4 PDO, 1 Scarf, and resection arthroplasties (Keller procedure) in 5 cases (Table 2). All cases experienced a painful recurrence of the deformity after a variable period of health, having achieved a correction by the primary surgery, so that they should be considered true recurrences or type III according to the classification proposed by Castellano [30], while HV deformities early following a surgical correction which had been never or insufficiently achieved (type I and II) were excluded from this study. The average time between the primary surgery and the PDO revision procedure was 9.7 years (range, 2–23).

All cases were treated with a PDO according to the original technique [25,27]. Seventeen feet presented transfer metatarsalgia assessed by the combination of patient's complains and the presence of hyperkeratosis under the metatarsal heads. For this reason, combined procedures were performed in 14 feet (43.7%): lesser distal metatarsal osteotomies in 13 cases with a minimally invasive Wolf–Jimenz–DeOrio technique [31], while in 1 case an extensor digitorum longum lengthening of second toe with arthrolysis of second metatarsophalangeal joint was performed.

2.2. Surgical procedure

Surgery was performed with a minimally invasive technique by ankle block anesthesia [32]. The patient is placed in supine position, with a below-knee wedge bracket allowing 90° of knee flexion and a plantigrade position of the foot on the operating table. The surgical procedure can be facilitated using fluoroscopy to monitor some of the following steps: distal-to proximal 2 mm. Kirschner wire insertion, medial to the base of the distal and to the proximal phalanx as far as the medial aspect of the first metatarsal head; a 5–7 mm skin incision, made in a subcapital site, at the metatarsal neck, checking the correct position by fluoroscopy during the learning curve; sparse periosteal detachment by small scissors; distal retrocapital osteotomy of the first metatarsal by a micromotorized bone cutter, performed by a series of small holes, as a corticotomy, using the bone cutter from inside to outside of the medullary canal in a circumferential way, thus avoiding damages of the surrounding structures; correction of the first IMA by lateral displacement and medio-lateral tilting of the capital fragment for correction Distal Metatarsal Articular Angle (DMAA); stabilization with the wire insertion into the proximal metatarsal (Figs. 1B and 2C); postoperative taping for an immediate weightbearing [25,27,28].

Table 2
list of previously performed surgical procedures prior to recurrence.

Primary procedures	
Soft tissue (25%)	8
Medial capsule retension	2
Mc Bride	6
First metatarsal or phalangeal osteotomy (59.4%)	19
Austin	4
Austin + Akin	2
Proximal osteotomy	3
Proximal osteotomy + Akin	1
Lamprect–Kramer	2
Akin	2
P.D.O.	4
Scarf	1
Arthroplasties (15.6%)	5
Keller	5

2.3. Clinical evaluation

Clinical outcomes were assessed before surgery and at the time of final follow-up with the American Orthopaedic Foot and Ankle Society (AOFAS) metatarsophalangeal–interphalangeal score for the hallux [33]. The questionnaire consists of 9 items that are distributed over 3 categories: pain (40 points), function (50 points) and alignment (10 points). These are all scored together for a total of 100 points. Patients were also assessed with use of the Coughlin Score, which classifies the results in relation to the patient's subjective satisfaction as excellent, good, fair and poor [34].

The Short Form-36 (SF-36) was also applied at final follow-up: this is a 36-item questionnaire which measures Quality of Life (QoL) across 8 domains, including 4 physically and 4 emotionally based domains [35,36]. The 8 domains that the SF36 measures are as follows: physical functioning, role limitations due to physical health, role limitations due to emotional problems, energy/fatigue, emotional well-being, social functioning, pain and general health. The higher the score the less disability, a score of 0 is equivalent to maximum disability and a score of 100 is equivalent to no disability.

In patients undergone a bilateral procedure, AOFAS and Coughlin's scores were considered separately for each foot, while it was not possible for the SF36 score (quality of life).

All clinical complications were also recorded.

2.4. Radiographic evaluation

Anteroposterior (AP) and lateral (LL) weightbearing radiographs of the foot were taken preoperatively, immediately postoperatively, at 3 and 6 months and at 1 year after surgery to assess consolidation of the osteotomy, and at the time of final follow-up.

Radiographic outcomes were assessed by measuring preoperatively and at final follow-up HVA, IMA and DMAA on weightbearing AP radiographs [37]. In particular, post-operative measurements were assessed considering the axis of the first metatarsal that line running from the middle point of the base to the middle point of the articular surface of the head [38].

Preoperative radiographs demonstrating HV recurrence were analyzed for possible etiologies of recurrence.

2.5. Statistical analysis

All chart and radiographic assessments were performed by a blinded, independent examiner (orthopaedic surgeon). Wilcoxon signed-rank test was used to analyze the difference of the preoperative and follow-up AOFAS and SEFAS scores.

3. Results

Patients were assessed with an average follow-up of 9.8 ± 4.3 years (range, 2.4–15.2). Clinical and radiographical results are summarized in Table 3. All patients reported the disappearance or reduction of the pain that they had experienced prior to the operation around the first metatarsal head: 20 cases (62.5%) reported total disappearance of the pain, 7 cases (21.8%) had only occasional pain, 5 cases (15.6) had daily moderate pain, and no patient had severe or constant pain.

The mean overall AOFAS score improved from 46.9 ± 17.8 points (range, 24–75) to 85.2 ± 14.9 points (range, 52–100) at the time of final follow-up showing a significant increase ($P < 0.05$). The mean pain score was 34.6 ± 7.6 points of the 40 points maximum on the

Table 3
Clinical and radiographical results. AOFAS: American Orthopaedic Foot and Ankle Society score; IMA: first intermetatarsal angle; HVA: hallux valgus angle; DMAA: Distal Metatarsal Articular Angle.

	Preoperative	Postoperative	Improvement	P
Mean AOFAS	46.9 ± 17.8	85.2 ± 14.9	38.3	<0.05
Mean IMA	11.4° ± 4.5°	6.6° ± 4°	4.8°	<0.05
Mean HVA	26.1° ± 9.1°	10.5° ± 6.3°	15.6°	<0.05
Mean DMAA	15.2° ± 6.5°	7.3° ± 4.9°	7.9°	<0.05

AOFAS scale and the functional capacity, which was measured by summing the scores for 6 different aspects of functional performance averaged 38.2 ± 5.6 points (maximum score on the scale 45 points).

The maximum score for toe alignment (15 points, indicating excellent or good alignment) was recorded for 21 feet (65.6%); a mild, asymptomatic malalignment (a score of 8 points) was recorded for 10 feet (31.2%); 1 foot with symptomatic malalignment (a score of 0 points) was recorded. The mean score for the involved toe alignment was 12.3 ± 3.9 points.

Patient subjective satisfaction according to the Coughlin classification was excellent in 15 feet (46.8%), good in 10 feet (31.3%), fair in 5 feet (15.6%) and poor in 2 feet (6.3%).

The mean overall physical components score of SF-36 0-100 was 61.9 ± 15.5 points, while emotional component scored 62.0 ± 13.9 points at the time of final follow-up.

The preoperative and follow-up AOFAS scores was compared with use of the Wilcoxon signed-rank test showing a significant difference with a $P < 0.05$.

Preoperatively, there was a transfer metatarsalgia in 17 feet while, at the time of follow-up, 10 cases were solved and seven remained unchanged due to severe mechanical insufficiency of the first ray. Among these 7 persistent metatarsalgia, 6 had been treated operatively, while 1 conservative. No patient reported new or increased metatarsalgia. There were no cases of nerve injury or neuritis.

The mean HVA value decreased from 26.1 ± 9.1 to 9.7 ± 5.4° and the mean IMA value decreased from 11.5 ± 4.5 to 6.7 ± 4.0° on weightbearing AP radiographs, while DMAA value decreased from 15.2 ± 6.5 to 7.3 ± 4.9° (Table 3). The postoperative radiographic assessments of HVA, IMA and DMAA showed a significant change ($P < 0.05$), compared with the preoperative values. Radiographic preoperative assessment did not allow to properly define the recurrences' etiologies.

All osteotomies except 1 radiographically healed within 3 months.

Complications included 1 case with a delayed consolidation of the osteotomy, healed after 1 year, 2 cases with a reduction of the MTPJ1 ROM less than 30°, both without pain, and in 1 case a re-recurrence of the deformity at a 14-years follow-up. No major complications, such as AVN of the metatarsal head, deep infection, upcoming transfer metatarsalgia or stress fracture of the near metatarsal bones were observed.

4. Discussion

The cause of recurrent HV is usually multifactorial, including patient-related factors such as preoperative anatomic predispositions, medical comorbidities, poor compliance with postoperative instructions, and surgical factors such as the choice of the most appropriate procedure and technical skills [39]. Among other reasons, insufficient lateral displacement or failure to perform a distal first metatarsal osteotomy, causing insufficient or no correction of an increased IMA, can lead to recurrence [19,30]. Moreover, certain procedures have specific shortcomings that may predispose to recurrence, for example a "simple bunionectomy" or a distal soft-tissue procedure when a significant metatarsus primus varus is present. This should be carefully considered in presence of an apparently recurrent HV, because these cases are probably suitable for a re-do primary surgery, unless in presence of irreversible anatomical surgical changes as in case of resection arthroplasties or metatarsal osteotomies with large displacement of the fragments, in which even a new traditional primary surgery can be difficult to perform.

Recurrent HV presents multiple challenges to the treating surgeon and it should be important being asked why and how did the original surgery fail. If a clear reason cannot be identified, one must carefully examine which revision procedure will reliably address that recurrent deformity. Revision procedures consist of either MTPJ1 fusion or joint-motion-retaining surgery; the latter is confined to correct the existing deformity, while usually does not typically solve the problem of instability, which is the underlying cause for most of the complications occurring after a resection arthroplasty (Table 1) [17,40]. MTPJ1 fusion is probably the best indication in presence of severe joint instability or painful ROM less than 30°. Revision procedures' failure can be caused by surgeon's reasons: as well as whether the most appropriate surgical procedure was not selected, or poor surgical technique was performed; by deformity's features or by a poor patient's compliance to an appropriate postoperative management. Therefore revision surgery often presents a high rate of complications as summarized in Table 1, which can reach up to 50–80% of the cases, especially following a salvage Keller arthroplasty [13–18]. For this reason, looking for new revision surgical option among MIS techniques, which can be burdened by a lower incidence of complication related to extensive approaches, could be reasonable.

This study showed that PDO enabled us to achieve a good correction of a recurrent HV deformity with a relative low complication rate in 32 feet, when compared with traditional procedures. A substantial reduction of pain was observed in our patients; the overall clinical results were entirely comparable with those reported with traditional salvage procedures (Table 1) and, for what concerns the considered clinical scores, appear even not so dissimilar from those of primary surgery. Better results were observed when a soft-tissue surgery alone had been performed in the primary procedure, and this because a distal osteotomy of the first metatarsal was performed in a condition very similar to a primary surgery; on the other hand, worse results were obtained in recurrences following a resection arthroplasty, when instability of MTPJ1 was impossible to satisfying address by the single osteotomy, which cannot have the biomechanical stabilizing effect of a fusion. Nevertheless, good results were achieved in those cases following a metatarsal osteotomy, both Austin (Figs. 1C–E and 2D, E) and Scarf procedure, where an inappropriate modification of the bony alignment had probably been primarily obtained. The relative poor number of cases and the heterogeneity of the primary procedures, could be considered as a limit of this study, whose aim was also to evaluate the PDO's efficacy and versatility in different situations in order to define its strengths and weaknesses.

The positive changes in the measured radiographical parameters following consolidation of PDO fulfill the biomechanical requirements for a correct distal osteotomy of the first metatarsal. We should ask how could a so apparently simple procedure, without any soft tissue release or plication, as PDO, be so effective in a recurrent deformity. Substantially an effect of a pure bony correction, sometime even with elements of a slight temporary overcorrection, could be proposed. First, a severe varus deviation of the first metatarsal bone and the sesamoids' dislocation can be addressed, even partially, by the large amount of lateral displacement of the capital fragment, up to 90–100% of the metatarsal diameter, which can be achieved by this kind of osteotomy; in this study, however, the sesamoids' position was not measured. Second, a MTPJ1 incongruence, often requiring an extensive open release in order to obtain an anatomical reduction which can be ineffective due to the poor quality of joint-surrounding soft tissues, could be otherwise corrected by the extensor-flexor tendons realignment or, on the other hand, in case of severe stiffness, by a lateral–medial tilt of the entire capital fragment with, as authors' trick, an overcorrection of the first metatarsal articular surface orientation, which can be detected by the measurement of DMAA as reported in Table 3. Third, a residual hallux pronation is easily addressed by the rotation on the frontal plane of the metatarsal head which is allowed by the technique. In addition, this procedure can regain the lost metatarsal length by the burr width by an oblique direction of the osteotomy medial to lateral and proximal to distal. The amount of lengthening, as well as shortening, is established pre-operatively, according to the surgical planning, and in some cases a first metatarsal lengthening could be not advisable. As result, no patients reported new or incremented metatarsalgia. Of course, to obtain so many corrective actions by a so apparently simple percutaneous osteotomy could appear unreliable or difficult to maintain, but our clinical and radiographical results seem to validate these hypothesized biomechanical effects. Undoubtedly, even for experienced foot and ankle surgeons, well familiarized with MIS forefoot techniques, HV revision surgery by a PDO should be considered a second-level procedure, needing an appropriate learning curve; the key point appears to be a careful preoperative planning in order to identify the deformity's features the most convenient to be addressed by a pure bony procedure as PDO. Moreover, as technical tricks, a careful positioning of the distal-to-proximal K-wire insertion as first step of the procedure, well stabilized to the bony prominence of the metatarsal head, and the appropriate site of the osteotomy, whose inclination on the axial plane allows to determine a shortening or a lengthening effect appear to be determinant.

5. Conclusion

PDO for revision of recurrent hallux valgus deformity is configured as a procedure capable of combining the advantages of MIS to a good correction of the deformity with a significant relief of the symptoms. A potential reduction of the risk of associated complications is promising for success in revision surgery. This study indicate that this technique allows to obtain good medium and long-term results, proving to be a safe and reliable procedure even for recurrent HV, regardless of the kind of performed primary surgery and it could be considered a viable alternative to traditional salvage procedure which have been mostly used to date for revision hallux valgus surgery. Further studies are needed to confirm this indication, in particular for what concerns the procedure's safety and a potential low complication rate.

Conflict of interest

The authors declare that there is no conflict of interest.

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