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This study presents clinical and radiological outcome of a percutaneous technique for the correction of hallux valgus and lesser toe deformities.

We present a 36 months follow-up series of 32 patients who have been treated with the Reverdin-Isham osteotomy for the correction of hallux valgus, and a percutaneous technique for the correction of lesser toes deformities and metatarsalgia. Clinical outcome data were recorded with the AOFAS score. Radiologic evaluation consisted of weight bearing (AP, lateral and Walter-Muller) views pre and postoperatively at 6 weeks, 3, 6, 12 and 36 months after surgery.

At three year follow-up, the mean difference of the HVA was 9.2 ($p < 0.0001$), of the IMA was 0.4 ($p < 0.001$), and the mean difference of the PASA was 15.9 ($p < 0.001$). The AOFAS rose from 48.4 to 87.6. Most encountered complication was oedema that lasted for 6 months, especially in the patients who underwent the Weil osteotomy of II, III and IV metatarsal bone head for the treatment of metatarsalgia.

Many minimal invasive techniques are becoming more and more recognized, with some indisputable advantages but also not free of objective difficulties. We believe that percutaneous distal metatarsal bone osteotomy represents a good option for the treatment of mild- to moderate hallux valgus, lesser toes deformities and metatarsalgia.

Hallux valgus; Forefoot deformities; Percutaneous osteotomies

Reverdin-Isham osteotomy for the treatment of mild-to-moderate hallux valgus

Percutaneous Weil osteotomies for correction of lesser toes deformities

3-year follow-up series of patients treated with percutaneous technique

Good clinical and radiographic results.

Hallux valgus is a common forefoot deformity; it occurs with a lateral deviation of the great toe and medial deviation of the first

metatarsal, progressively leading to the subluxation of the first metatarsophalangeal joint [1]. In advanced stage it is associated with the dorsal displacement of the second, third and fourth toe that causes increased plantar pressure on the heads of the metatarsal bones; this leads to a chronic metatarsalgia and a typical plantar hyperkeratosis [2]. According to MJ Coughlin (Table 1) it is possible to classify the pathology into 3 grades of severity based on the value of the Hallux Valgus Angle (HAV normal $< 20^\circ$), First Intermetatarsal Angle (IMA normal $< 11^\circ$), Proximal Articular Set Angle (PASA normal $< 6^\circ$), first metatarsophalangeal joint congruency and the position of sesamoids. Surgical correction is indicated in patients reporting pain and difficulty wearing shoes. More than 150 procedures have been described for the correction of these forefoot deformities [3] distal metatarsal osteotomy is recommended to correct mild-to-moderate deformity with IMA exceeding 15° or to correct the Proximal Articular Set Angle. Many minimally invasive or percutaneous techniques have been reported for the distal first metatarsal osteotomy, with or without internal fixation.

	$< 20^\circ$	$< 11^\circ$	Congruent Joint	Anatomic position, occasionally 50% subluxation of the lateral sesamoid
	$20-40^\circ$	$11-16^\circ$	Incongruent Joint	75%-100% displacement of the lateral sesamoid

	40°	16-18°	Subluxated Joint Severe pronation of the hallux	100% lateral subluxation of the lateral sesamoid
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as possible. After the first month the correction is kept with an orthoplasty maintaining the first ray alignment.

Patients were discharged a few hours after the surgery, they received 30 days of low molecular weight heparin as antithrombotic prophylaxis, 5 days of Amoxicillin and the postoperative analgesia consisted in a combination of paracetamol and codeine. Follow-up visits were set weekly for a month in order to change the dressings.

Data were analyzed using the statistical software PASW Statistics version 20.0 (IBM®SPSS®Statistics). The preoperative recorded data (HVA, IMA, PASA, AOFAS) have been compared with the postoperative values. Data were tested for normality. When data were

The functional results were evaluated at one and 3-year follow-up. The AOFAS score improved significantly ($p < 0.001$); the median score at 3 years was 87.6 ± 12.6 compared to the pre-operative median score of 48.4 ± 15.8 , showing patient satisfaction (Table 4).

Pre-Op	55.5 (IQR 18)
12 Months FU	88.0 (IQR 15)
36 Months FU	92.0 (IQR 22.7)
Mean Diff. Pre-OP, Last FU	-40.9
P-Value	<0.0001

Table 4 Clinical results (median score and IQR).

In the past years, many different techniques have been described for the correction of hallux valgus.

In foot surgery, the minimally invasive surgical approach allows the surgeon to execute surgery through small incisions, with no direct exposure of surgical planes, and with minimal trauma to the soft tissues.

This technique was first described in 1945 by Morton Pollock, and it has been modified and adjusted by many different authors [8].

Bosch in 1990 [9], described the Bosch osteotomy for hallux valgus, modifying the Hohmann technique; De Prado and Ripoll also in 1990, began to use the techniques described by Isham, expanding the indications.

In Italy, in 1997 Bartolozzi [10] and Magnan [10] described the PDO (Percutaneous Distal Osteotomy) and Giannini [11] in 2003, described the SERI (Simple Effective Rapid Inexpensive).

The results reported in literature demonstrated that the more recent minimally invasive approach osteotomies are comparable with the traditional techniques (such as Scarf and Chevron osteotomies).

Maffulli et al. [12] compared two groups of patients; 36 of them had a minimal incision subcapital osteotomy of the first metatarsal, and 36 of them underwent a Scarf osteotomy. Results of the AOFAS and FAOS (Foot and Ankle Outcome Score) were similar in the two groups.

Radiological results showed that in the Scarf group the HVA passed from $28^\circ \pm 6$ to $20^\circ \pm 6$, the IMA passed from $14^\circ \pm 3$ to $8^\circ \pm 4$, and the PASA passed from $12^\circ \pm 6$ to $7^\circ \pm 5$.

In the Mini-Incision Osteotomy group the HVA passed from $27^\circ \pm 6$ to $17^\circ \pm 4$, the IMA passed from $15^\circ \pm 6$ to $8^\circ \pm 3$, and the PASA decreased from $11^\circ \pm 5$ to $7^\circ \pm 4$.

The results of this study confirmed the benefits of the minimal incision distal metatarsal osteotomy, given the reduced mean operative time and the comparable results obtained with the traditional technique.

Bauer et al. in 2010 [6] published a two-year clinical and radiological results on 82 patients, using the Reverdin-Isham

osteotomy. Functional results improved; the median AOFAS score rose from 49/100 preoperatively to 87.5/100.

Radiological results showed that the median HVA passed from 30° (25-32) to 15° (11-18). The IMA from 14° (12-15) preoperatively to 11° (9-13); and the PASA changed from 15° (12-18) to 7° (4-10).

The authors reported some cases of M1 and F1 lateral cortex fractures that did not require revision; 6 cases of PASA hypercorrection, 2 cases of joint stiffness, 2 cases of complex regional pain syndrome, and 3 cases of recurrence of the deformity.

Magnan et al. in 2005 [13] reported a 5-year follow-up on 82 patients (118 feet) treated with the PDO.

The mean total score for AOFAS assessment was 88.2 ± 12.9 .

HVA preoperatively was $31.5^\circ \pm 10.2$ and postoperatively $13.7^\circ \pm 6.7$. The IMA changed from $12.3^\circ \pm 3$ to $7.3^\circ \pm 2.7$. The PASA decreased from $14.2^\circ \pm 6.4$ to $6.7^\circ \pm 4.6$.

Consolidation of the osteotomy was confirmed in all patients at six months radiographically. They reported the motion of the first metatarsal joint limited to $< 30^\circ$ in eight feet; one case of deep infection at the osteotomy site and no cases of secondary hallux varus.

Giannini et al. in 2013 [14] published a prospective study on 641 patients treated with the SERI technique. The AOFAS score rose from 46.8 ± 16.7 to 89 ± 10.3 . The mean HVA value decreased from $32^\circ \pm 8.3$ preoperatively to $13.3^\circ \pm 6.4$ at the last follow up. The mean IMA value decreased from $14.3^\circ \pm 3.3$ to $6.9^\circ \pm 3.6$ at the last follow up. The mean PASA value decreased from $13.5^\circ \pm 5.3$ preoperatively to $6.5^\circ \pm 4.4$ at the last follow up. No cases of non-union were reported; dorsal malunion was observed in eight feet, and recurrence occurred in 47 feet (5.3%).

The results of our prospective single-centre study demonstrates that the percutaneous distal metatarsal osteotomies can be considered as a valid alternative to currently existing techniques used to correct forefoot deformities. In our experience we found the Reverdin-Isham technique and Akin osteotomy very effective to correct the hallux valgus and the percutaneous Weil osteotomy useful to correct lateral ray deformities.

We obtained a good correction of the HVA and PASA, but we did not correct the IMA. As assessed by Bauer et al. [15] the Reverdin-Isham osteotomy is a reliable technique for the correction of isolated mild-to-moderate hallux valgus deformities, without significant metatarsus varus, elevated HVA and incongruent MTP1 joint. In our series we reported 3 cases (9.3%) of relapses in preoperative severe deformity.

In these cases a different surgical technique would have been more adequate, perhaps one that provides an internal fixation of the osteotomies.

Following other authors, we pointed out that the Reverdin-Isham osteotomy provides significant functional improvement, comparable to results obtained with other percutaneous first-ray distal metatarsal osteotomy procedures, with or without osteosynthesis [4] (Table 5).

