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# Percutaneous Distal Osteotomies of the Metatarsal Bones: Surgical Technique and Results

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## Abstract

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

**Methods:** 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.

**Results:** At three year follow-up, the mean difference of the HVA was 9.2 ($p<0.0001$), of the IMA was 0.4 ($p<6719$), 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.

**Conclusion:** 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.

**Keywords** Hallux valgus; Forefoot deformities; Percutaneous osteotomies

## Highlights

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.

## Introduction

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 associate with the dorsal displacement of the second, third and forth 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°), First Intermetatarsal Angle (IMA normal <11°), Proximal Articular Set Angle (PASA normal <6°), 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.

| MILD DEFORMITY | HVA | IMA | MTPJ CONGRUENCY | SESAMOID POSITION |
|---|---|---|---|---|
| | < 20° | < 11° | Congruent Joint | Anatomic position, occasionally 50% subluxation of the lateral sesamoid |
| **MODERATE DEFORMITY** | 20-40° | 11-16° | Incongruent Joint | 75%-100% displacement of the lateral sesamoid |

| | | | | |
|---|---|---|---|---|
| **SEVERE DEFORMITY** | ≥40° | 16-18° | Subluxated Joint<br>Severe pronation of the hallux | 100% lateral subluxation of the lateral sesamoid |

**Table 1:** Classification of Hallux Valgus Deformity [18].

The Reverdin osteotomy revised by Isham, is a percutaneous procedure without fixation, to align the first ray by medial rotation of the first metatarsal head and PASA correction this technique represents a valid procedure that allows the correction of hallux valgus reducing morbidity and surgical time [4]. The Akin procedure is the osteotomy of the first phalanx of the greater toe, it should be performed in presence of an increased Distal Articular Set Angle (DASA), and is indicated in most patients [3].

The percutaneous Weil osteotomy is indicated in case of chronic metatarsalgia mostly due to a first ray deficiency. Enables shortening and elevation of the metatarsal bone heads through a small incision that limits formation of dorsal fibrosis, penetration of the joint to prevent stiffening, and without internal fixation allowing immediate weight bearing [5]. The aim of this study is to show the clinical and radiological results of percutaneous surgery to correct forefoot deformities after a minimum 3-year follow-up.

## Material and Methods

A continuous prospective single-centre, single-surgeon series of 32 patients of hallux valgus was managed by the same percutaneous technique between January and June 2012. The surgical treatment was offered only in case of pain, functional impairment and problems wearing shoes. We included 10 cases with mild deformity of hallux valgus, 18 cases with moderate deformity and 4 cases with severe deformity. The median age was 55.5 years (range, 21 to 78 years), there were 29 women and 3 men; 20 patients had surgery at right foot and 12 at the left foot. Clinical examination data were recorded by experienced surgeons and orthopaedic residents, for each patient, preoperatively and in postoperative follow-up. All the patients had been evaluated for type and duration of the symptoms, range of motion (ROM), presence of callosities, other deformities and history of metatarsalgia. Clinical evaluation was then summarized in the hallux-metatarsophalangeal-interphalangeal scale proposed by the American Orthopaedics Foot and Ankle Society (AOFAS) [6] preoperatively, at 12 and 36 month follow- up. This questionnaire provides a score ranging from 0 to 100 points calculated on 3 domains: pain (maximum score 40 points), functional capability (maximum score 45 points) and hallux alignment (maximum score 15 points). Anteroposterior, lateral weight-bearing and Walter-Muller views X-rays were taken preoperatively, at 6 weeks, 3, 6, 12 and 36 months after the surgery. Several manual measurements were made on each image, by two observers: Hallux Valgus Angle (HVA), First Intermetatarsal Angle (IMA), the Proximal Articular Set Angle (PASA), Distal Articular Set Angle (DASA) and the congruency of the first metatarsolphalangeal joint.

## Surgical Technique

All the surgeries were performed by the same expert surgeon following the technique described by Isham and De Prado et al. [2].

The procedures were performed as day surgery, under loco-regional anaesthesia. The patient was in supine position with the operated heel over the edge of the table and the contra lateral knee bend; no tourniquet was ever used during the surgery. A 3-5 mm incision was performed in the medial and plantar edge of the first-metatarsal head in order to separate the capsule from the bunion by a sweeping movement using a specific elevator. At first the medial and dorsal protrusion of the first metatarsal head were resected using a conical burr on a drill set at low speed (2000-7000 rpm), the resection was monitored by fluoroscopy to ensure a sufficient resection. The bone fragments were evacuated manually with a pressure and with saline lavage and cleansing using a specific rasp; this process was repeated as many times as necessary to achieve the buniectomy. The Revedin-Isham osteotomy was performed by a straight burr using the same medial approach, and it was applied to the flat bone surface resulting from bunion removal at an angle of about 45° to the long axis of the first metatarsal bone, in the dorsal-distal-plantar-proximal direction conserving the lateral cortex. The burr speed was set at 2000-8000 rpm, and the osteotomy was performed starting on the medial aspect, using a gentle back-and-forth sweeping movement. The hallux was then manually placed in a forced varus position. This procedure was performed under fluoroscopy control; the osteotomy creates a wedge with a medially oriented base, which, when it is closed, modifies completely the orientation of the articular surface, normalizing the altered PASA. No internal fixation was ever performed. The next step requires a dorsolateral approach in order to perform a transverse abductor tenotomy by Beaver® blade. A third approach was then made to execute the Akin osteotomy of the first phalanx, 3 mm medially to the extensor hallucis tendon. A straight burr was used for proximal metaphyseal osteotomy of the phalanx, under fluoroscopy, conserving lateral cortex. Percutaneous Weil osteotomy of second, third and forth metatarsal bone's heads was performed in presence of metatarsalgia in 22 cases (68.7%). Lesser toes deformities such as hammer toe were treated with extensor tenotomy, occasionally flexor tenotomy and osteotomy of the first phalanx in 3 cases. The average surgical time was 18.5 minutes (range 15-22) when only the Reverdin-Isham osteotomy and the Akin osteotomy were performed; the time increased to 32 minutes (range 28-36) in those cases requiring also the Weil osteotomy of the second, third and fourth metatarsal bones.

## Postoperative Care

The post operative dressing of the foot assumes a crucial role in obtaining the best outcome possible achieved through these percutaneous osteotomies without the use of internal fixation [7]. The gauzes were wrapped between the hallux and the second toe. In order to keep the splint in a straight position the first gauze crosses the medial aspect of the Reverdin-Isham osteotomies, the second one crosses more distally in order to cover the Akin osteotomy, in a slight hypercorrection. When second, third and fourth metatarsal osteotomies were performed a thick bandage was placed below the distal metatarsal bone heads. Immediate weight bearing was allowed with a rigid flat soled orthopaedic shoe which is indicated for the first 4 weeks following the surgery. It was also recommended, especially during the first week, for patients to keep their leg elevated for as long

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 Analysis

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 normally distributed means and standard deviations were given, for non-normal distributed median and interquartile range (IQR) differences between pre and postoperative angles were tested with a paired t-test. The Wilcoxon signed-rank test was used to assess difference between independent variables. The level of significance was set at $p<0.05$.

The significance of the changes has been determined with the use of the Student's T test, with a significance level of 0.05 (p value <0.05) using the statistics software package SPSS statistics version 22 (IBM, USA).

## Results

All patients were followed up for at least 36 months, with a mean follow-up of 39.5 months (range 36-43 months). None were lost at 36 months follow-up.

Radiological evaluation consisted of weight bearing (AP, lateral and WM) views preoperative and post-operative at 6 weeks, 3, 6, 12 and 36 months after surgery; the day of the surgery, before discharging the patients non weight bearing AP and lateral views were also taken.

Each radiographic feature, manual measurement and healing status of the osteotomies were assessed by two observers non involved in the surgery.

Postoperatively a significant reduction in the hallux valgus angle was obtained, with a median angle of 3.4° respect to preoperative median value of 25.4° ($p<0.05$). The median PASA angle decreased from 21.4° preoperatively to 8.9° postoperatively ($p<0.05$). The median IMA decreased from 12° preoperatively to 8.8° postoperatively ($p<0.05$). The value changes of HVA and PASA angles being statistically significant ($p<0.05$).

At 3 months the HVA angle showed a median value of 10.9°, the median PASA angle was 8.5° and the median IMA angle was 11.4°. At 3-year evaluation the median HVA angle was 16.1° and the median PASA was 6.1° with a significant mean improvement of 9.3° (HVA) and 15.9° (PASA) respect to preoperative values ($p<0.05$).

No statistical significant reduction was observed in the median IMA at end of follow up (Table 2).

| | HVA | IMA | PASA |
|---|---|---|---|
| **Pre-Op** | 25.4° ± 8 | 12° ± 3.2 | 21.4° ± 12.7 |
| **Post-Op** | 3.4°± 8.5 | 8.8° ± 3 | 8.9° ± 7 |
| **3 Months FU** | 10.9° ± 7.2 | 11.4° ± 2.6 | 8.5° ± 7.8 |
| **6 Months FU** | 11.8° ± 6.3 | 11.8° ± 2.9 | 8.5° ± 7.8 |
| **12 Months FU** | 16.0° ± 6.3 | 12.2° ± 3.2 | 6.1° ± 4.4 |
| **36 Months FU** | 16.1° ± 6.4 | 11.1° ± 2.9 | 6.1° ± 4.1 |
| **Mean Diff. Pre-OP,Last FU** | 9.2 | 0.4 | 15.9 |
| **P-Value** | < 0.0001 | 0.67 | < 0.0001 |

**Table 2:** Radiographic results (mean difference and standard deviation).

The follow-up analysis of radiographic results showed a partial loss of hallux correction compared to postoperative X-rays. The loss of correction is due to the hypercorrection given in the post operative care, with the dressing and the orthoplasty.

Consolidation of the osteotomy site was confirmed radiographically within 6 months in 30 patients, 2 of the patients were diagnosed with delayed union.

The complications occurred with this minimally invasive technique are shown in (Table 3).

| Complications | Percentage |
|---|---|
| Oedema (lasted for 6 months) | 71.8% |
| Pain (lasted for 12 months) | 15.6% |
| Relapses | 9.3% |
| Superficial skin infection | 3.1% |
| Delayed union | 6.2% |
| Paresthesia (spontaneous resolution) | 6.2% |
| MTP1 joint stiffness | 9.3% |
| Complex Regional Pain Syndrome | 3.1% |

**Table 3:** Complications.

Oedema was the most frequent complication: 71.8% of the patients; it occurred mostly (100%) in the cases treated with Weil osteotomy of II, III and IV metatarsal bone head, as shown even in other studies [4]. The oedema gradually healed resuming the everyday physical activity and wearing comfortable shoes; it could last for 6 months after the surgery.

Post operative pain occurred especially during the first week, persistent pain occurred in the 15.6% of cases one year after the surgery. Relapses occurred in the 9.3% of patients with preoperative severe hallux valgus deformity. MTP1 joint stiffness occurred in 9.3% of the patients. Delayed union occurred in two cases (6.2%) without any bone callus 6 month after the surgery.

Two patients reported paresthesia of temporary nature only. Skin infection occurred in just one case, one patient showed skin burn due to the burr, and one more patient developed complex regional pain syndrome.

Normal footwear was resumed at a mean 6 weeks (range 4-8 weeks) after percutaneous correction of isolated hallux valgus, and a mean 9 weeks (range 6-12 weeks) in case of associated lateral metatarsal osteotomy.

The functional results were evaluated at one and 3-year follow-up. The AOFAS score improved significantly (p value<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).

| Follow up | AOFAS |
|---|---|
| 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).

## Discussion

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 Polokoff, 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 HAV passed from 28° ± 6 to 20° ± 6; the IMA passed from 14° ± 3 to 8° ± 4; and the PASA passed from 12° ± 6 to 7° ± 5.

In the Mini-Incision Osteotomy group the HAV passed from 27° ± 6 to 17° ± 4; the IMA passed from 15° ± 6 to 8° ± 3, and the PASA decreased from 11° ± 5 to 7° ± 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° ± 10.2 and postoperatively 13.7° ± 6.7. The IMA changed from 12.3° ± 3 to 7.3° ± 2.7. The PASA decreased from 14.2° ± 6.4 to 6.7° ± 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° 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° ± 8.3 preoperatively to 13.3° ± 6.4 at the last follow up. The mean IMA value decreased from 14.3° ± 3.3 to 6.9° ± 3.6 at the last follow up. The mean PASA value decreased from 13.5° ± 5.3 preoperatively to 6.5° ± 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 T 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).

| 1st Author And Year Of Publication | F.U. (Months) | No. of Patients | Surgical Technique | HVA Pre-Op | HVA Post-Op | IMA Pre-Op | IMA Post-Op | PASA Pre-Op | PASA Post-Op | AOFAS Pre-Op | AOFAS Post-Op |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Present series | 36 | 32 | Reverdin-Isham Osteotomy | 25.4° ± 8 | 16.1° ± 6.4 | 12.1° ± 3.3 | 11.1° ± 2.9 | 21.5° ± 12.8 | 6.2° ± 4.2 | 51 (IQR 25) | 92 (IQR 22.7) |
| Maffulli et al. [12] | 30 | 36 | Scarf Osteotomy | 28° ± 6 | 20° ± 6 | 14° ± 3 | 8° ± 4 | 12° ± 6 | 7° ± 5 | 51 ± 13 | 86 ± 8 |
| | | 36 | Bosch Osteotomy | 27° ± 6 | 17° ± 4 | 15° ± 6 | 8° ± 3 | 11° ± 5 | 7° ± 4 | 54 ± 10 | 85 ± 11 |
| Bauer et al. [4] | 24 | 82 | Reverdin-Isham Osteotomy | 30° (25-32) | 15° (11-18) | 14° (12-15) | 11° (9-13) | 15° (12-18) | 7° (4-10) | 49/100 | 87.5/100 |
| Magnan et al. [13] | 35.9 | 82 | PDO | 31.5° ± 10.2 | 13.7° ± 6.7 | 12.3° ± 3 | 7.3° ± 2.7 | 14.2° ± 6.4 | 6.7° ± 4.6 | - | 88.2 ± 12.9 |
| Giannini et al. [14] | 84 | 641 | SERI | 32° ± 8.3 | 13.3° ± 6.4 | 14.3°± 3.3 | 6.9° ± 3.6 | 13.5° ± 5.3 | 6.5° ± 4.4 | 46.8 ± 16.7 | 89 ± 10.3 |
| Diaz Fernandez [17] | 24 | 36 | Reverdin-Isham Osteotomy | 40.02° ± 6.50 | 10.51° ± 6.55 | 16.88° ± 2.01 | 8.18° ± 3.23 | 16.09° ± 7.46 | 9.52° ± 6.36 | 48.14 ± 4.79 | 91.28 ± 8.73 |

**Table 5:** Comparison of techniques: Clinical and radiographic results.

The main complication in our series was the oedema that lasted for 6 months (71.8%), but we reported that this condition was shown mostly in the patients who underwent II, III and IV metatarsal bone heads' Weil osteotomies.

Recently Henry et al. [16] have published a study that compares the classic Weil osteotomy with a percutaneous Distal Metatarsal Mini-invasive Osteotomy (DMMO). This procedure consists in an extra-articular osteotomy without internal fixation, similar to the one performed in our series.

The authors found that oedema and metatarsalgia were significantly more common in the patients who underwent the DMMO technique during the evaluation at 3 months after surgery. The surgical recovery was longer after a DMMO; oedema was present at 3 months in 29% of the patients after the Weil osteotomy versus 59% of the patients after DMMO, but in the DMMO group the oedema was transient and completely gone at 12 months.

The present study has certain limitations; it is an observational study and not comparative or randomized. Furthermore, the present series involves a small number patients and the statistical power is not high due. The minimum follow-up of 3 years would require a longer-term assessment to confirm the present clinical and radiographic results.

Our series was homogenous for patient selection, surgical procedure and postoperative care. The functional results obtained at 36 months follow-up demonstrated a median AOFAS score of 87.7 ± 12.6 points. This value expresses the high patient's satisfaction regarding this technique mostly due to the percutaneous approach which presents aesthetic advantage and allows immediate weight-bearing deambulation.

In conclusion, we believe that percutaneous distal metatarsal bone osteotomies, with adequate training to achieve fine reproducibility and a strict postoperative dressing protocol, allows shorter surgical times, less soft tissue damage and fast-track recovery for the patients with mild-to-moderate forefoot deformities.

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