Distal percutaneous osteotomy of the first metatarsal bone for the correction of Hallux Valgus: SERI versus percutaneous chevron technique. A cadaveric study

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Abstract

Background:

Distal first metatarsal osteotomy is used to correct mild or moderate Hallux Valgus (HV), and multiple surgical techniques have been described. Percutaneous surgery for HV uses small skin incisions to correct the forefoot deformity, and shorter recovery times and fewer complications have been reported.

Distal first metatarsal osteotomy is used for the correction of mild or moderate HV, and multiple surgical techniques have been described. We designed a cadaveric study to compare the resistance to axial load between two distal first metatarsal osteotomies, SERI and percutaneous chevron, both of which are non-fixated techniques. The first aim of this study was to develop a systematic technique for measuring the sagittal displacement on lateral foot X-ray. Our second objective was to measure the resistance to axial load in both these osteotomies.

Methods:

Ten pairs of freshly frozen cadaveric feet were randomly assigned to one of the two techniques investigated. Pre- and post-operative X-rays were obtained. After surgery, the feet were placed under progressive axial loads up to 60 kg. Joint angles and bone distances were measured and differences between the two techniques were statistically assessed.

Results:

SERI osteotomy gave a significantly higher plantar displacement when the axial load was under 30 kg. From over 30 kg there were no significant differences between the two techniques. Metatarsal head displacement under axial load was less variable with chevron osteotomy. Plantar angulation was increased in both techniques.

Conclusions:

Although the chevron technique confers higher stability regarding fragment displacement during axial loading, both techniques increase the plantar angulation of the metatarsal head.

Level of Evidence

Cadaveric study. Level V.

Background

Percutaneous forefoot surgery to correct Hallux Valgus (HV) is reported to have advantages over open surgery, such as fewer cutaneous/infectious complications, shorter procedural time, and quicker post-operative recovery [1, 2, 3].
Distal first metatarsal osteotomies (DFMO) are normally indicated for treating moderate hallux valgus, with intermetatarsal angle between 12 and 20 degrees [4]. Numerous percutaneous DFMO have been described using different shapes of osteotomy and with or without osteosynthesis [4, 5, 6]. Although most authors performing percutaneous DFMO prefer to combine the osteotomy with a cannulated screw [7], some techniques have been described using minimal fixation (Kirschner wire) or no fixation whatsoever [3, 6, 8]. There have been few studies comparing DFMO techniques, and those published to date usually compare an open procedure with a percutaneous one [9, 10]. However, most publications report the results of one specific operative technique [2, 4, 11, 12]. Moreover, most studies focus on the AP X-ray view; stability in the sagittal plane is seldom included.

In the present study, set in an anatomy laboratory, we compared two common non-fixated percutaneous distal first metatarsal osteotomies. The first, SERI (simple, effective, rapid, inexpensive), was described by Giannini et al. [3] in 2001 but was based on a technique described by Bösch in 1990 [11]. It consists of a linear osteotomy at the metatarsal neck level using a Kirschner wire as a lever to lateralize the metatarsal head. As the metatarsal head is not traversed by the K-wire, this is not classed as a fixation method. The second procedure was a percutaneous chevron osteotomy, a V shaped osteotomy at the metatarsal neck level without hardware stabilization. For both techniques, the authors allowed immediate ambulation using postoperative shoes that transfer weight-bearing to the hindfoot [3]. Even with this shoe, the axial forces acting on the forefoot during full weight-bearing ambulation are still remarkable [13] and could potentially affect non-fixated osteotomies.

The first objective of our study was to develop a systematic and reproducible way of measuring displacement on a lateral foot X-ray. The second objective was to assess the behavior of these two surgical techniques under a controlled axial load.

**Methods**

**Study design and specimens**

Two percutaneous non-fixated DFMO were compared: percutaneous chevron osteotomy and SERI osteotomy.

Ten pairs of freshly frozen cadaveric adult feet were obtained from a body donation program of XXXXXXX following the legal procedures and ethical framework governing body donation in our country. The authors state that every effort was made to follow all local and international ethical guidelines and laws that pertain to the use of human cadaveric donors in anatomical research [14]. Each specimen consisted of a whole foot and the distal third of the tibia and fibula. Specimens with scars or histories of trauma or surgery were excluded. The age at death of the specimens ranged from 62 to 84 years. Before starting the procedures, the feet were thawed at room temperature.

**Surgical technique**
The two surgical techniques were distributed randomly, so that a different technique was applied to each foot in a pair. All surgical procedures were performed under fluoroscopic control with the assistance of a C-arm (OEC Brivo, General Electrics, Boston, Massachusetts, USA).

- **Chevron osteotomy**: The chevron osteotomy (Fig. 1A) was created using a 2 mm diameter and 15 mm length Shannon burr. It was placed on the dorsal part of the metatarsal at the level of the neck of the bone (junction between the distal metaphysis and diaphysis of the first metatarsal) and a vertical osteotomy was started, moving towards the plantar aspect of the metatarsal. Once the dorsal half of the bone was cut, the direction of the osteotomy changed, heading proximally in an almost horizontal manner. A V-shaped osteotomy was thereby achieved with an angulation of approximately 90 degrees.

- **SERI osteotomy**: For the SERI osteotomy (Fig. 1B) we also used a 2 mm by 15 mm Shannon burr. This osteotomy also started on the dorsal part of the metatarsal at the level of the neck of the bone. In this technique, the direction moved gradually plantar and proximal so the osteotomy was diagonal. Once it was achieved, a 2 mm K-wire was inserted, starting from the medial corner of the nail of the big toe and heading proximally, just medial of the phalanges and metatarsal head. The K-wire was inserted into the metatarsal bone, proximal to the osteotomy, in an intramedullary fashion (Fig. 2).

- **Bandaging**: The feet were bandaged using specifically designed dressings as described by de Prado [6], which helped maintain the correction achieved by the osteotomies.

**Radiological assessment**

Fluoroscopy imaging was obtained during the procedures with a C-arm and saved in a digital format. All the measurements were made later by an external radiologist.

Lateral fluoroscopic images of the feet were taken before the surgery and after surgery and bandaging. Afterwards, using a torque-based force bench (Fig. 3), axial weight was loaded on to the foot, progressing in 10 kg increments up to 60 kg. Lateral X-rays were taken at every 10 kg increase.

Two parameters were measured on the lateral images:

1. **Metaphysio-diaphyseal angle (MDA)**. This is formed between a line that follows the dorsal cortex of the first metatarsal diaphysis and a line that follows the dorsal cortex of the first metatarsal metaphysis (Fig. 4).

2. **Distance between the osteotomy fragments**. This was represented by a line starting at the proximal part of the dorsal cortex of the metaphysis, perpendicular to the dorsal cortex of the diaphysis (Fig. 5).

**Statistical analysis**
Significant differences between the two techniques either in MDA or in the distance between osteotomy fragments distance were assessed using a Student t-test for all loads and for every 10 kg axial load increase.

The significance threshold was set at a two-sided alpha value of 0.05. SPSS software (SPSS 20 for Mac, IBM, Chicago USA®) was used for all analyses.

Results

The MDA decreased in both surgical techniques, meaning that the metatarsal head tilted plantarly. The mean plantar tilt was −6.90 degrees (SD = 10.251) for chevron osteotomy and −5.34 degrees (SD = 16.621) for SERI osteotomy. There was no significant difference between the techniques (p = 0.41). Progressively increasing the load on the foot did not change this tendency (p = 0.553) (Table 1).

Table 1
Changes in metaphysio-diaphyseal angle measured in degrees on the lateral X-ray view

<table>
<thead>
<tr>
<th>Axial load (kg)</th>
<th>SERI</th>
<th>Chevron</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>-0.8 ± 17.6</td>
<td>-7.3 ± 9.6</td>
<td>P 0.453</td>
</tr>
<tr>
<td>20</td>
<td>-4.3 ± 15.7</td>
<td>-8.4 ± 7.1</td>
<td>P 0.516</td>
</tr>
<tr>
<td>30</td>
<td>-4.1 ± 17.8</td>
<td>-8.3 ± 8.1</td>
<td>P 0.517</td>
</tr>
<tr>
<td>40</td>
<td>-4.7 ± 16.4</td>
<td>-9.1 ± 8.1</td>
<td>P 0.458</td>
</tr>
<tr>
<td>50</td>
<td>-6.5 ± 12.8</td>
<td>-9.2 ± 11.6</td>
<td>P 0.628</td>
</tr>
<tr>
<td>60</td>
<td>-6.8 ± 13.3</td>
<td>-7.8 ± 12.9</td>
<td>P 0.867</td>
</tr>
</tbody>
</table>

Regarding the distance between bone fragments, SERI produced more plantar displacement than chevron, which was statistically significant for the 10 and 20 kg loads (p = 0.031 and 0.04 respectively) (Table 2). As the load on the foot increased, the metatarsal head moved upwards in the SERI technique, so the plantar displacement decreased (Fig. 6). At loads ≥ 30 kg the bone fragment distance did not differ significantly between the techniques (p = 0.114), though chevron osteotomy remained more stable throughout the load test.
Table 2
Distance between bone fragments, in millimeters, measured on the lateral x-ray view.

<table>
<thead>
<tr>
<th>Axial load (kg)</th>
<th>SERI</th>
<th>Chevron</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>-4.3 ± 4.2</td>
<td>0.5 ± 1.8</td>
<td>P 0.031</td>
</tr>
<tr>
<td>20</td>
<td>-2.9 ± 0.8</td>
<td>0.3 ± 1.3</td>
<td>P 0.04</td>
</tr>
<tr>
<td>30</td>
<td>-3.2 ± 3.5</td>
<td>-0.7 ± 2.8</td>
<td>P 0.114</td>
</tr>
<tr>
<td>40</td>
<td>-2.5 ± 3.3</td>
<td>-0.5 ± 2.8</td>
<td>P 0.150</td>
</tr>
<tr>
<td>50</td>
<td>-2.2 ± 3.2</td>
<td>-0.6 ± 2.5</td>
<td>P 0.227</td>
</tr>
<tr>
<td>60</td>
<td>-2.2 ± 3.6</td>
<td>-0.1 ± 2.3</td>
<td>P 0.143</td>
</tr>
</tbody>
</table>

Discussion

Hallux valgus is a frequent deformity of the first digit of the foot, with progressive abduction and pronation of the first phalanx. There is adduction, elevation, and pronation of the first metatarsal (metatarsal primus varus) concurrent with lateral capsule retraction of the metatarsophalangeal (MTP) joint [8]. In addition to its esthetic effect, hallux valgus changes the foot dynamics, leading to what Viladot defined as a first radius insufficiency [15]. Inflammation of the bursa overlying the medial eminence of the metatarsal head causes pain and discomfort, and irritation of the dorsal medial cutaneous nerve of the hallux [6, 17]. First radius insufficiency can also lead to second and third metatarsal head overload [18, 19]. Therefore, when surgery is indicated, it is essential to correct the metatarsus primus varus as well as the hallux valgus [20]. For moderate hallux valgus (intermetatarsal – IMTT- angle < 20 degrees) this can be achieved with a DFMO [3]. For greater deformities, other techniques such as proximal osteotomy of the first metatarsus can be indicated [21].

Many open surgery procedures have been described for osteotomy of the distal first metatarsal, but not until the 1980s did minimally invasive and percutaneous procedures start to appear [22]. The authors believed that the benefits from percutaneous hallux valgus surgery (esthetic improvement, soft tissue conservation, shorter surgical time, shorter recovery time, and better postoperative pain control) outweigh the potential risk of neurovascular or tendon injury, which is minimal [23]. The first widely disseminated percutaneous procedure, published by Bauer et al [8], was a variation of Reverdin osteotomy (medial closing wedge osteotomy at the metatarsal distal third) together with an Akin osteotomy, adductor tenotomy and buniection [6]. None of the osteotomies were fixated with hardware. This procedure corrects both the Hallux Valgus angle (HVA) and MDA but does not improve the IMTT angle, and it is not recommended for cases with IMTT angle greater than 12–13 degrees [5, 24].

To achieve greater IMTT angle correction, Bosch et al. [11] designed a new DFMO, not taking a wedge but using a Kirschner wire as a lever to help move the metatarsal head laterally. This procedure was later popularized by Giannini et al. as Simple, Effective, Rapid and Inexpensive technique (SERI). Giannini et al.
[3] published some very good radiological and functional results, although they described dorsal
displacement of the metatarsal head in a very few patients (1%). To avoid this, they recommended a thick
K-wire (2.0 mm). However, as the K-wire does not traverse the metatarsal head, its thickness is not
necessarily key to the stability of the osteotomy, and SERI should be considered a non-fixated technique.
Other authors performing SERI have found much greater metatarsal head dorsal displacements (12–
20%) [25, 26], even up to 60% [4]. This displacement could lead to shortening of the first metatarsal,
which could produce secondary transference metatarsal pain.

Percutaneous chevron osteotomy was first described by Vernois and Redfern [7, 27]. It is a V-shaped
osteotomy in which the first part is dorsal, short, and vertical and the second part is plantar, longer, and
almost horizontal [17]. It allows the HVA, MDA and IMTT angles to be corrected. Vernois and Redfern
described percutaneous chevron osteotomy with a screw fixation between the bony fragments, but we
used no hardware fixation. Austin [28], who first described chevron osteotomy during the 1960s,
considered the V-shaped osteotomy inherently stable, and open surgery studies show that chevron
osteotomy confers no advantage in fragment fixation [29, 30]. For this reason, and in order to compare
the stability of the osteotomy shape between SERI and chevron under similar conditions, we decided to
perform the percutaneous chevron osteotomy without fixation.

Radwan et al. [10] compared the SERI technique with an open chevron, both fixated only with a K-wire.
However, to our knowledge, no comparisons of SERI and percutaneous chevron osteotomies have been
published. Most of the studies we reviewed only focused on the AP X-ray view, measuring HVA, DMA and
IMTT angle, and did not assess stability in the sagittal plane. Some authors [3, 4, 9, 31] report dorsal
malunion but do not specify how they measured it. Only Faour-Martin et al. [25] specify that they
measured the percentage of the transverse diameter of the osteotomy line on lateral X-ray, finding 29% of
dorsiflexion on average, but this only assessed the bony displacement and did not consider angulation.
We have described a method that allowed us to measure both the fragment distance and the angulation
systematically on lateral X-ray. To our knowledge, this is the first study to take into account changes in
MDA in the sagittal plane.

With the SERI technique, we observed a plantar displacement of 4.3 mm and a plantar angulation of 0.8
degrees with no load. As the load on the foot increased progressively, the plantar displacement decreased
(2.2 mm at 60 kg axial load), but the plantar angulation of the metatarsal head continued to increase up
to 6.8 degrees at 60 kg load. This variability during the stress test shows that SERI osteotomy is highly
unstable in the sagittal plane.

With chevron osteotomy there was less fragment displacement. With no load there was a dorsal
displacement of 0.5 mm, which remained quite stable, and at 60 kg load the displacement was a 0.1 mm.
Chevron displacement was significantly less than SERI when the load was less than 30 kg. However, from
30 kg, as the plantar displacement of SERI decreased, this statistical difference disappeared. The 0.1 mm
displacement at 60 kg load in chevron osteotomy was lower than the 2.2 mm in SERI, but the difference
was not significant.
On the other hand, chevron osteotomy gave 7.3 degrees plantar angulation, which remained quite constant, reaching 7.8 degrees at 60 kg load (mean 6.9 degrees over all loads). Therefore, although there was less displacement of the bony fragments, chevron osteotomy failed to control the metatarsal head angulation, even though this angulation change remained stable during the loading test.

Studies investigating both the SERI and chevron techniques typically report dorsal metatarsal head displacement [3, 22, 31]. However, we observed plantar displacement in all cases. This could be explained as follows: since the plantar displacement decreased as the load on the foot increased, allowing patients to weight-bear post-operatively probably helps to displace the osteotomy upwards.

Although our study could have revealed greater differences between these two surgical procedures if more subjects had been examined, the fragment angulation in the sagittal plane shows unacceptable instability in both techniques. A 5–6 degrees change in metatarsal head angulation could disturb the metatarsal formula and lead to iatrogenic metatarsalgia, or potentially to limitation of the flexion-extension of the metatarsophalangeal joint. We believe both techniques could benefit from sturdier fixation such as screw fixation.

**Conclusions**

In the sagittal plane, chevron osteotomy was more stable than SERI in terms of fragment displacement. Although SERI gave greater variability in angulation during the stress test, both techniques showed increased plantar angulation of the metatarsal head. For this reason, screw fixation could be advisable.

**Abbreviations**

DFMO
distal first metatarsal osteotomies
HV
*Hallux Valgus*
HVA
*Hallux Valgus* angle
IMTT
intermetatarsal
MDA
metaphysio-diaphyseal angle
MTP
metatarsophalangeal
SERI
simple, effective, rapid & inexpensive technique

**Declarations**
The study was approved by the Research Ethics Committee (CEI) of the University Hospital of Girona (CEI Girona).

All data generated or analysed during this study are included in this published article.

The authors declare that they have no competing interests.

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**Authors’ contribution**

EN-C: project development, data collection, data analysis, manuscript writing

KA G-N: data analysis

AC: data collection, manuscript writing

RST: data analysis, manuscript writing, final revision

MA S-C: data analysis, manuscript revision

JI: manuscript edition, final revision

SV: data collection

FR: project development, data analysis, manuscript writing, final revision

All authors read and approved the final manuscript

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**References**


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Figures
Figure 1

Sagittal view of the osteotomies. **A.** Chevron osteotomy: an initial vertical cut is made from the dorsal aspect of the neck of the first metatarsal bone to the middle of the bone in the sagittal plane. The direction of the osteotomy then changes, heading proximally in an almost horizontal direction. **B.** SERI osteotomy: a diagonal linear osteotomy is performed from the dorsal aspect of the neck of the first metatarsal, moving plantarly and proximally.
Figure 2

Anteroposterior view of the SERI procedure. Once the osteotomy is achieved, a 2.0 mm K-wire is inserted from the toe, heading proximal just medial of the phalanges and metatarsal head. Once it reaches the proximal part of the osteotomy, the K-wire is introduced into the metatarsal bone in an intramedullary fashion.

Figure 3

Torque-based force bench. Its design allowed a stable attachment of the tibia to be made. A vertical force could be applied and measured by a dynamometer (Mecmesin Ltd, Slinfold, United Kingdom).
Figure 4

Measurement of metaphysio-diaphyseal angle on lateral X-ray.

Figure 5

Method used to measure fragment displacement on lateral X-ray. On the left, dorsal displacement of the metatarsal head can be observed in a lateral X-ray of a SERI osteotomy. On the right, the same X-ray with the displacement measurement. A line is drawn following the metatarsal diaphysis (continuous black line), which continues distal to the osteotomy (dashed line). A line perpendicular to the diaphyseal line is
drawn (red line) from the start of the metaphyseal fragment (blue cross). This measures the distance between fragments.

**Figure 6**

Evolution of a SERI osteotomy under progressive axial load on the foot. Note the plantar displacement of the metatarsal head at 10 kg load, which is progressively reduced as the head is displaced dorsally when the axial load is increased. At 60 kg load, the position of the head is almost anatomical.