Efficacy of first metatarsophalangeal joint lateral release in hallux valgus surgery

R. Augoyard\textsuperscript{a,*}, A. Largey\textsuperscript{b}, M.-A. Munoz\textsuperscript{c}, F. Canovas\textsuperscript{c}

\textsuperscript{a} Saint-Charles Private Hospital, 25, rue de Flesselles, Lyon, France
\textsuperscript{b} Champeau Méditerranée Hospital, 32, avenue Enseigne-Albertini, Béziers, France
\textsuperscript{c} Department of orthopaedics III, Lapeyronie Teaching Hospital Center, 371, avenue du Doyen-Gaston-Giraud, Montpellier, France

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KEYWORDS
Hallux valgus; Lateral release; Surgery

Summary

Introduction: Lateral release of the sesamoid ligament complex is one of the key steps to the surgical treatment of hallux valgus. Although numerous techniques are available to perform this procedure, there is no accepted consensus on the method of choice. The goal of this study was to evaluate the efficacy of sequential release of lateral soft tissue structures for correction of hallux valgus deformity.

Patients and methods: This study included 40 patients, mean age 50.9 years old (± 17.4), with 49 hallux valgus deformities from mechanical causes. The first metatarsophalangeal angle (M1P1), the intermetatarsal angle (M1M2) and the position of the sesamoids in relation to mechanical axis of M (according to the Research Committee of the American Orthopedic Foot and Ankle Society) were determined on preoperative X-rays. During the procedure, lateral release was performed in several steps: sectioning the metatarsosesamoid suspensory ligament then sectioning the phalangeal insertional band (PIB) and complete detachment of the adductor on the fibular sesamoid ligament. We measured the changes in the M1P1 and M1M2 angles during this step-by-step release.

Results: The M1P1 angle decreased during each step of release and went from 29.9° to 11.1° (P < 0.001). The M1M2 decreased by 1.7° following medial capsulorrhapsy. Simple capsulorrhapsy reduced the hallux valgus deformity by 8.2° (44%). Release of the metatarsosesamoid suspensory ligament resulted in a decrease of 3.9° (or 21% of total release), release of the PIB in a decrease of 5.1° (27%) and complete detachment of the adductor in a decrease of 1.5° (8%). Thirty-six percent of the sesamoids were reduced after metatarsosesamoid ligament resection, 56% after PIB release, and 60% after adductor release.

Discussion: Lateral soft tissue release is ensured in most cases by sectioning the metatarsosesamoid suspensory ligament and the PIB. Release of the adductor from the fibular sesamoid has a limited effect.

* Corresponding author.
E-mail address: romaugoy@yahoo.fr (R. Augoyard).
Introduction

The pathologic anatomy of hallux valgus includes retraction of the lateral capsulo-ligamentary elements, distension of the medial capsule, increase in metatarsus varus and lateral subluxation of the proximal phalanx. This deformity is associated with severe imbalance of the muscles of the first ray which causes the deformity to worsen over time [1,2]. More than 200 surgical techniques have been described, however none of them seem to apply to all types of hallux valgus. The success of these operations depends upon associating several surgical techniques. One of these is common to all operations: lateral release of the sesamoid ligament complex. Anatomical studies of the latero-planter angle have identified the elements on the lateral side of the sesamoid ligament complex that are retracted and responsible for attachment of the hallux valgus [2–4].

The technique used for lateral release of the sesamoid ligament complex varies among authors. In the literature, release includes sectioning of the lateral metatarsosseamoid ligament associated or not with sectioning of the phalangeal insertion band (PIB) and complete detachment of the adductor of the hallux on the fibular sesamoid [1,5,6]. Lateral release is a key step in hallux valgus surgery. It has not been extensively studied, which explains why there is no consensus on the way it should be performed. It is generally accepted that if lateral release is not performed the risk of recurrence is increased [4,7]. However, its efficacy and its role in reducing the hallux valgus deformity is not well known.

We performed a prospective experimental clinical study of sequential release of different points of attachment to evaluate the efficacy of release of these different points on correction of the M1P1 angle and on the position of the sesamoids. The goal was to obtain a consensus to standardize release of the lateral side of the sesamoid ligament complex, and to determine what should be sectioned according to the severity of the deformity.

Patients and methods

Included patients

This was a continuous prospective study performed between January 2009 and July 2010. Only patients with hallux valgus from mechanical causes were included (M1P1 $\geq 15^\circ$), and patients with inflammatory rheumatic diseases (rheumatoid arthritis... ) or connective tissue diseases (Marfan syndrome, Ehlers-Danlos syndrome) were excluded. The hindfoot was normally aligned. Patients had no history of surgery on the hindfoot or the forefoot.

We included 49 hallux valgus (26 right feet, 23 left feet) in 40 patients. Nine patients underwent surgery in both feet. The population was mainly women (5 men, 35 women). The mean age at inclusion was 50.9 years old $\pm$ 17 (19–76). All patients had metatarsophalangeal joint pain due to the deformity.

Preoperative radiological assessment

All patients underwent dorsoplantar view X-rays of the foot according to the quality criteria reported by Besse et al. [8].

The radiological parameters measured on the AP view X-rays were the metatarsophalangeal angle of the first ray (M1P1), the first intermetatarsal space angle (M1M2) and the level of sesamoid dislocation according to the Research Committee of the American Orthopaedic Foot and Ankle Surgery [9].

The M1P1 angle was measured between the mechanical axis of M1[10] and the metaphyseal-diaphyseal axis of the proximal phalanx (P1) of the hallux. The value was positive for a hallux valgus and negative for a hallux varus. The M1M2 angle was measured between the mechanical axis of M1 and the metaphyseal-diaphyseal axis of the second metatarsal. We classified dislocation of the sesamoid ligament complex into four stages (Fig. 1):

- stage 0 (normal) with an M1 axis passing between the two sesamoids;
- stage 1 (pinching) with an M1 axis tangent to or slightly intersecting the edge of the medial sesamoid (Sm);
- stage 2 (subluxation) with an M1 axis passing $\pm 1$ mm through the center of Sm;
- stage 3 (dislocation) with $\text{Sm}$ passing more or less completely through the lateral side of the M1 axis.

Surgical technique

Patients underwent surgery by the same surgeon under general or locoregional anesthesia. A pneumatic tourniquet was placed at the root of the limb. The study of lateral release was performed before any osteotomy on M1 or P1. A medial approach was taken in all cases with a horizontal arthroscopy of the metatarsophalangeal joint. Lateral release of the joint was performed with a second dorsal incision in the first intermetatarsal space. Release of the sesamoid ligament complex was performed in steps and always in the same order.
Release of the first 29 feet was studied in three steps

The following points of attachment were sectioned in the same order:

- the lateral metatarsosesamoid ligament;
- the PIB and its attachment to P1;
- complete detachment of the adductor of the hallux from the fibular sesamoid.

After each step, a medial capsulorrhaphy by X-suture was performed based on the medioplantar angle to correctly reposition the sesamoid ligament complex under the head of M1. Weight bearing plantigrade fluoroscopic images were obtained of the patient’s foot on the operating table. The fluoroscopy was positioned to have a beam incidence angle of 15°−20°, which is necessary to obtain good quality X-rays of the forefoot.

A fourth step was added to the procedure for the 30th to 49th foot

This step as performed before any release procedure, and before sectioning of the sesamoid-metatarsal ligament. This step included stabilization of the sesamoids by performing the medial capsulorrhaphy suture after the arthroty. This step was considered step 0. These were the different steps of the procedure: (0) sesamoid stabilization; (1) sectioning of the lateral metatarsosesamoid ligament; (2) sectioning of the PIB and its attachment to P1; (3) complete detachment of the hallux adductor from the fibular sesamoid.

Study methods

Analysis of fluoroscopic images

Images were recovered and transformed into DICOM format to be analyzed using a software that processes medical imaging (Myrian, module XP-Ortho V1.1.0, Intraseense SAS, Montpellier, France). The M1P1 angle, the M1M2 angle and the stage of sesamoid dislocation were measured for each image [9]. We calculated the angle of correction of M1P1 for each step to determine the percentage of release provided by each step. The angle of correction provided by step 1 was not only due to sectioning of the metatarsosesamoid ligament. Some reduction of the hallux valgus deformity is possible in all patients, and this was calculated by step 0, so that the percentage of correction provided by sectioning of the sesamoid-metatarsal suspensory ligament could then be obtained. For the sesamoid dislocation index, a stage of zero was considered normal.

Reducibility of deformities depending on the severity of the hallux valgus

Mann et al. [1] have classified hallux valgus into different stages of severity depending on the size of the M1P1 and M1M2 angles. We used this classification to analyze the reducibility of deformities in relation to the preoperative M1P1 and M1M2 angles. Mann et al. concluded that there was an increased risk of recurrence with the McBride procedure when the initial M1P1 angle was greater than 30°. Thus, we divided the M1P1 group (21°−39°) into two groups M1P1 (21°−30°) and M1P1 (31°−39°). Because the patient cohort was not large enough, we could not evaluate the importance of step 0 and step 1 in relation to the severity of the hallux valgus. We therefore analyzed steps 0 + 1, which corresponded to the results of release after stabilization of the sesamoid ligament complex and sectioning of the lateral sesamoid-metatarsal suspensory ligament. Finally, we analyzed hallux valgus deformities that were not reduced after three-step lateral release in relation to the preoperative M1P1 and M1M2 angles. The deformity was considered reduced when the M1P1 was less than 15°.

Statistical analysis

Statistical analysis was performed by the medical information technology department of the Montpellier CHU using SAS 9.1.3 software. A Student t test and a Wilcoxon non-parametric test were used. ROC (Receiver Operating Characteristic) curves were obtained to determine the thresholds of the preoperative M1P1 and M1M2 angles for which simple lateral release was not enough to reduce the hallux valgus deformity. One curve was obtained for the preoperative M1P1 variable (Fig. 2), and the other for the preoperative M1M2 variable (Fig. 3). After initial results were analyzed we decided to obtain these curves for surgical steps 2 and 3. Criteria for reduction were an M1P1 angle of less than 15° and stage 0 sesamoid dislocation.
Results

Radiological correction

The M1P1 angle decreased significantly after each step, from a preoperative mean 29.9° to 11.1° after the third step of release ($P < 0.001$). Correction of the M1P1 angle followed the same pattern. The M1M2 angle decreased significantly between the preoperative stage (preop stage) and the first step from a mean 11° to 9.3° or a mean decrease of 1.7°. There was no significant variation in the M1M2 angle after release steps 1, 2 or 3 (Table 1).

Reduction of the M1P1 angle provided by each step of release

The M1P1 angle in the 20 feet that underwent step 0 for sesamoid stabilization decreased by 8.2° (1°—21°) which corresponded to 44% of total M1P1 correction after step 3. Step 1 release including sectioning of the metatarsos-sesamoid ligament resulted in 21% of the total correction of the M1P1 angle. Sectioning of the PIB provided 27% of the total correction at step 3, and complete detachment of the adductor from the fibular sesamoid only provided 8% of the correction of the M1P1 angle (Fig. 4).

Progression of the sesamoid dislocation index

Thirty-six percent of the sesamoids were reduced after step 1 and 56% after step 2. Reduction of the sesamoids was obtained in two steps because the final step only provided additional sesamoid reduction in 4% of patients. Details on the progression of the dislocation index are summarized in Fig. 5.

Radiological correction in relation to the severity of the hallux valgus

Analysis in relation to the preoperative M1P1 angle

The greater the preoperative M1P1 angle, the greater the decrease in the M1M2 angle (Table 2). It decreased by a mean of 1.5° in the M1P1(15°—20°) group while it decreased by
2.8° in the M1P > 40° group. When the preoperative M1P was > 30°, the mean M1P angle after steps 2 and 3 was > 15°, and more than half the deformities were not reduced after steps 2 and 3. We were able to calculate the percentage of decrease in the preoperative angles provided by each step of release in relation to the size of the initial M1P angle. Steps (0 + 1) ranged from 70% to 53% while step 2 ranged from 28% to 38%. The reduction in the sesamoid dislocation index in relation to the initial M1P angle was usually obtained during the first two steps of release. If a reduced sesamoid was considered to be stage 0, 100% of the sesamoids were reduced after the second step in the M1P (16°–20°) group, and 73.3% in the M1P (21°–30°) group respectively. Reduction was less effective in hallux valgus deformities > 30°, with 37.5% of the sesamoids reduced after step 2 in the M1P (31°–39°) group and 25% in the M1P > 40° group. The third step only provided reduction of the sesamoid in 6.3% and 12.5% in each group respectively.

Analysis in relation to the preoperative M1M2 angle
The M1M2 intermetatarsal angle decreased significantly between step 0 and step 1 but not between steps 1, 2 and 3. In deformities with a preoperative M1M2 angle < 9°, the M1M2 angle went from 7.1° to 6.7° after step 0 + 1 (P < 0.05). In deformities with a preoperative M1M2 angle of between 9 and 11°, the intermetatarsal angle decreased from 9.9° (preop step) to 8.8° after step 0 + 1 (P < 0.05). The intermetatarsal angle decreased from 13.6° to 10.8° in deformities with an M1M2 angle ≥ 12 (P < 0.05).

The sesamoid dislocation index progressed significantly during the first two steps. If sesamoids were considered reduced at an index of 0, 89% of the sesamoids were reduced after step 2 in M1M2 group < 9°, 65% in M1M2 group (9°–11°) and 33.3% in M1M2 group ≥ 12, respectively.

Analysis of the reducibility of deformities
More than 50% of the sesamoids were not reduced when the initial M1P angle was greater than 30° and when the initial M1M2 angle was greater than 9° (Table 3).

ROC curves: identifying threshold values
There were no significant differences in the ROC curves after steps 2 and 3. We searched for threshold values predictive of insufficient correction after step 2.

The preoperative threshold M1P1 value obtained with the ROC curves was 26° (Fig. 2) with a sensitivity of 90%, a specificity of 71% (that is 71% of sesamoids were reduced after step 2 with a preoperative M1P1 angle of less than 26°), a positive predictive value of 83% and a negative predictive value of 83%.

The threshold preoperative M1M2 obtained with the ROC curves was 9° (Fig. 3) for a sensitivity of 93%, a specificity of 33% (that is 33% of sesamoids reduced after step 2 with a preoperative M1M2 angle of less than 9°), a positive predictive value of 66% and a negative predictive value of 78%.

Discussion
Our study of step-by-step lateral soft tissue release shows that stabilization (step 0) was the most effective step for

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**Table 1** Progression of radiographic parameters after each step of release.

<table>
<thead>
<tr>
<th></th>
<th>Preoperative(Preop step)</th>
<th>Step 1</th>
<th>Step 2</th>
<th>Step 3</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1P1 angle</td>
<td>29.5 ± 9.8</td>
<td>17.5 ± 8.2</td>
<td>12.5 ± 6.6</td>
<td>11 ± 4.8</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>M1M2 angle</td>
<td>10.9 ± 2.7 (S)</td>
<td>9.3 ± 2.5 (NS)</td>
<td>8.8 ± 2.5 (NS)</td>
<td>9 ± 2.4</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>M1P1 correction obtained</td>
<td>12 ± 4 (2–20)</td>
<td>17 ± 7 (2–44)</td>
<td>18.5 ± 8 (4–46)</td>
<td>&lt;0.001</td>
<td></td>
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</tbody>
</table>

S: significant; NS: not significant.

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**Table 2** Analysis of radiographic data in relation to preoperative M1P1 angle.

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>Number</td>
<td>10</td>
<td>31</td>
<td>15</td>
<td>16</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Preop M1M2</td>
<td>9.3</td>
<td>11</td>
<td>10.2</td>
<td>11.7</td>
<td>13.1</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>M1M2 after step 1</td>
<td>7.8</td>
<td>9.5</td>
<td>9.1</td>
<td>9.9</td>
<td>10.3</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Mean correction M1P1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between step preop -1</td>
<td>7.7 (70%)</td>
<td>12.7 (67%)</td>
<td>11.6 (71%)</td>
<td>13.8 (65%)</td>
<td>15.1 (53%)</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Between steps 1-2</td>
<td>3.1 (28%)</td>
<td>4.3 (23%)</td>
<td>4.2 (25%)</td>
<td>4.63 (22%)</td>
<td>10.6 (38%)</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Between steps 2-3</td>
<td>–0.2 (2%)</td>
<td>1.8 (10%)</td>
<td>0.7 (4%)</td>
<td>2.8 (13%)</td>
<td>2.5 (9%)</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Global</td>
<td>10.6 (100%)</td>
<td>18.5 (100%)</td>
<td>16.4 (100%)</td>
<td>21.2 (100%)</td>
<td>28.3 (95%)</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Mean M1P1 angle after step 2</td>
<td>7</td>
<td>12.8</td>
<td>9.4</td>
<td>16</td>
<td>19.4</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Mean M1P1 angle after step 3</td>
<td>7</td>
<td>11</td>
<td>8.6</td>
<td>13.2</td>
<td>16.8</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>N° cases M1P1 &gt; 15° after step 2</td>
<td>1 (10%)</td>
<td>13 (42%)</td>
<td>1 (11%)</td>
<td>12 (75%)</td>
<td>6 (75%)</td>
<td></td>
</tr>
<tr>
<td>N° cases M1P1 &gt; 15° after step 3</td>
<td>1 (10%)</td>
<td>9 (29%)</td>
<td>1 (11%)</td>
<td>8 (50%)</td>
<td>6 (75%)</td>
<td></td>
</tr>
</tbody>
</table>

In bold: the percentage of M1P1 correction apportioned by each step the sum of each step give the global (100%) M1P1 correction.
Table 3 Proportion of cases of hallux valgus reduced (M1P1 < 15°) after complete release.

<table>
<thead>
<tr>
<th>Preop M1P1</th>
<th>Preop M1M2</th>
<th>9°—11°</th>
<th>12°—17°</th>
<th>n total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>Not reduced: number and %</td>
<td>n</td>
<td>Not reduced: number and %</td>
</tr>
<tr>
<td>&lt; 15°</td>
<td>1</td>
<td>0 (100%)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>15°—20°</td>
<td>4</td>
<td>0</td>
<td>5 (20%)</td>
<td>1</td>
</tr>
<tr>
<td>21°—30°</td>
<td>3</td>
<td>0</td>
<td>7 (30%)</td>
<td>5</td>
</tr>
<tr>
<td>31°—39°</td>
<td>1</td>
<td>1 (100%)</td>
<td>5</td>
<td>3 (60%)</td>
</tr>
<tr>
<td>&gt; 40°</td>
<td>0</td>
<td>0</td>
<td>3 (100%)</td>
<td>5</td>
</tr>
<tr>
<td>n total</td>
<td>9</td>
<td>20</td>
<td></td>
<td>21</td>
</tr>
</tbody>
</table>

decreasing the M1P1 angle and was the only step that influenced a decrease in the M1M2 angle, which favors mobility of the cuneometatarsal joint. This mobility, which is related to medial capsular distension, is an element which must be taken into account during the correction of hallux valgus by stable repair of the medial capsular plane. In most cases, sectioning of the sesamoid-metatarsal ligament and the PIB corrects the hallux valgus deformity. Release of the adductor from the fibular sesamoid has never been studied. Its role in correcting hallux valgus and reducing sesamoid dislocation is limited. Thus it should not be detached. Reduction of the sesamoids under the head of M1 was mainly obtained by sectioning the metatarsosesamoid suspensory ligament and the PIB. More than 50% of the patients who presented with a preoperative hallux valgus deformity with an M1P1 angle > 30° and an M1M2 angle > 9° were not reduced after full release. The ROC curves provided threshold values for the preoperative M1P1 angles (26°) and M1M2 angles (9°) above which simple lateral release of the sesamoid ligament complex was insufficient to correct deformities.

Weight bearing images on the operating table and suture of the medial capsule performed for each step of release was a technical bias in this study, because they needed to be systematically performed in the same way for each patient and at each different step. To limit this bias, we chose to perform this study with one surgeon in a large cohort. Moreover, we changed the protocol slightly by adding step 0 with stabilization of the sesamoids after the first 29 operations and in the last 20 patients. This change in the protocol during the study (adding step 0 in the last 20 patients) results in a bias in the analysis of reducibility of the hallux valgus deformity after stabilization.

The strong point of this study is that it is unique. There are no other studies in the literature that have specifically evaluated the step-by-step efficacy of lateral release in the correction of hallux valgus.

Lateral release described by Silver in 1923 [11] included releasing the sesamoid suspensory ligament, the PIB and the intermetatarsal transverse ligament. McBride [12] added a lateral sesamoidectomy to this procedure with transfer of the adductor tendon to the head of M1. For McBride, this lateral release of the sesamoid ligament complex was the main element of the procedure, while for others it was one of the keys to correcting a hallux valgus deformity. Several techniques are described to perform lateral release in the series in the literature, from simple sectioning of the metatarsosesamoid suspensory ligament [13], to complete release of all attachments from the fibular sesamoid [14]. Baudet [15] sectioned the suspensory ligament and the associated tendon. In case of insufficient correction, he completely detached the adductor from the fibular sesamoid when necessary. Roth et al. [16] analyzed the efficacy of step-by-step lateral release with no associated procedures in the correction of hallux valgus deformity. Sectioning the metatarsosesamoid ligament then the adductor resulted in a decrease of 7.8° and 1.6° in the M1P1 angle respectively for an initial mean M1P1 angle of 28.4°. In certain studies, release also included complete sectioning of the intermetatarsal ligament and of the lateral collateral ligament. We feel that these are not necessary. Roth et al. [16] showed that sectioning of the intermetatarsal ligament did not decrease the M1P1 and M1M2 angles. Labovitz et al. [17] showed that a traumatic tear of the lateral collateral ligament could cause a hallux valgus deformity, and even controlled sectioning had the same effect: we therefore decided that this was not necessary.

Basile et al. [18] reported a 1°-decrease in the M1M2 angle with isolated lateral release while Mann et al. [1] observed a decrease of 5.2° with a modified McBride procedure. This decrease in the M1M2 angle is a sign of cuneometatarsal joint mobility. Coughlin et al. [19] feel that this hypermobility is the consequence and not the cause of hallux valgus, and is due to medial capsular distension.

For many years, modified or standard McBride procedures were used in most cases with satisfactory results in 91—96% of cases [20—22]. Mann et al. [23] estimated that the failures occurred when very large deformities were corrected, creating a risk of insufficient correction and requiring excessive release of the lateral sesamoid ligament complex, which is a source of hallux varus. They concluded that there was a high risk of failure when the preoperative angles (using the anatomic axis of M1) of M1M2 were greater than 15° and of M1P1 were greater than 30°. In the past few years, surgical treatment of hallux varus has been centered on the M1 osteotomy. Certain authors have tried to show that lateral release is unnecessary. [24,25]. However, Cranberry et al. [26] had better results when an M1 osteotomy was associated with lateral release.

The first choice of surgical treatment is lateral release as the main procedure. Lateral release associated
with stabilization of the medial capsular plane [27,28] could be effective in hallux valgus deformities with an M1M2 angle < 10° and M1P1 < 27°, as long as the surgical DMAA is normal and M1 is not too long. That would make it possible to prevent complications associated with M1 osteotomies, which occur in 1.9%–9.7% of cases. [29,30]

Conclusion

In practice, lateral release of the sesamoid ligament complex should include sectioning of the metatarsosesamoid suspensory ligament and detachment of the PIB at the base of P1. Reducibility of hallux valgus deformities must be taken into account in the surgical treatment of this entity.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

References