Anatomical Study of Minimally Invasive Lateral Release Techniques for Hallux Valgus Treatment

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Abstract
Background: Lateral release (LR) for the treatment of hallux valgus is a routinely performed technique, either by means of open or minimally invasive (MI) surgery. Despite this, there is no available evidence of the efficacy and safety of MI lateral release. Our aim was to study 2 popular techniques for MI LR in cadavers by subsequently dissecting the released anatomical structures.

Methods: Twenty-two cadaveric feet were included in the study and allocated into 2 groups, 1 for each procedure: 1 group underwent a MI adductor tendon release (AR), and in the other group, an extensive percutaneous lateral release (EPLR) (adductor tendon, suspensory ligament, phalanx-sesamoid ligament, lateral head of flexor hallucis brevis, and deep transverse metatarsal ligament) was performed. Anatomical dissection was performed to identify neurovascular injuries and to verify the released structures.

Results: Both techniques demonstrated to be effective in reproducing a MI LR. A satisfactory release of the adductor tendon was achieved equally in both techniques (P = .85), being partial in most EPLR cases and full in the majority of AR cases. The EPLR was successful in releasing the intended additional structures (P < .05). One case of inadvertent complete section of the flexor hallucis longus was identified in the percutaneous adductor tendon release group. No cases of dorsolateral nerve injury were seen with either of the techniques.

Conclusion: Percutaneous lateral release was a reliable and accurate technique in this cadaveric model. The MI AR proved to be more effective in fully releasing the adductor tendon while the ER was intended and able to release a number of other structures.

Clinical Relevance: MI LR is a safe procedure that could obviate the need for open surgery to achieve the same surgical goal. It can be associated to either open or MI osteotomies in the correction of hallux valgus.

Keywords: hallux disorders, forefoot disorders, minimally invasive surgery, lateral release

Hallux valgus (HV) is a common deformity. Among other factors, soft tissue structures around the first metatarso-phalangeal (MTP) joint are believed to play a role in its etiology.33 As a consequence, surgical treatment of HV must address soft tissue contractures in conjunction with bony realignment.9,26 A lateral release (LR) of the first MTP joint, consisting of a tenotomy of the adductor muscle and the release of other structures (suspensory ligament, phalanx-sesamoid ligament, conjoint tendon of flexor hallucis brevis) lateral to the first MTP joint is a commonly used procedure for soft tissue correction.

In recent years, an increasing interest in minimally invasive (MI) techniques for HV correction has been experienced because of lesser damage to soft tissues and a lower risk of wound complications.23 Numerous MI techniques have been described, and different osteotomies and the use of LR can be performed through percutaneous approaches. However, LR is a controversial procedure in the MI HV technique. Although some authors recommend LR6,10,14,26,37 others do not consider LR a necessary part of HV correction.4,17,25,28,39 Furthermore, as direct visualization of the anatomical structures is not obtained during MI procedures, it is difficult to be absolutely certain about the structures claimed to be released.4 It is known that the anatomy of the lateral part of the first MTP joint is complex.18,36 A release of the lateral part of the first MTP joint, including the adductor tendon, the

*References 1-3, 5, 7, 8, 12, 15, 16, 18, 21-23, 28, 29, 31, 32, 35, 36.
suspensory ligament, and the conjoint tendon of the flexor hallucis brevis (FHB) and adductor muscles (oblique and transverse portions), has been proposed to correct HV deformity. However, surgical techniques aiming to release 1 or several of the lateral structures of the first MTP joint claim different results with regard to the sectioned structures, with little evidence, especially those performed through a MI approach (Table 1).

The aim of this anatomical study was to identify the released structures after performing an MI technique and to compare 2 MI techniques: 1 aiming to achieve an isolated release of the adductor tendon and 1 aiming to release the suspensory ligament, the adductor tendon, and the lateral head of the flexor hallucis brevis tendon.

Methods

The study was conducted in the Department of Anatomy at our institution. Institutional review board approval was obtained. Twenty-two cadaveric feet were included in the study. Mean specimen age was 73 (range, 52-93) years. Fifteen specimens were female and 13 left.

All feet included in the study had HV of less than 10 degrees or no deformity. Exclusion criteria included feet with hallux varus or the presence of scarring due to previous surgery or a traumatic event.

Specimens were divided in 2 groups according to the technique used. Each group included 11 feet. In the first group, an isolated percutaneous adductor tendon release (PATR) was performed. In the second group, an extensive percutaneous LR (EPLR) was performed. EPLR included release of the suspensory ligament, adductor tendon, and any lateral sesamoid attachments, including the phalanx-sesamoid ligament, the lateral head of the flexor hallucis brevis tendon, and the deep transverse metatarsal ligament (ligament found between the lateral part of the lateral sesamoid and the plantar plate of the second MTP joint).

Both surgical techniques were performed by surgeons experienced in foot and ankle MI techniques. The PATR technique was performed by 1 surgeon, while the EPLR technique was performed by another surgeon. The surgical techniques were performed under x-ray control to verify the blade position. The LR was considered complete when the lateral aspect of the first MTP could be opened while the first toe was driven into varus. After the procedure, an experienced anatomist dissected all specimens.

Surgical Techniques

PATR technique. A 3-mm incision was made in the first web space at the level of the first MTP joint (Figure 1A). Under fluoroscopic control, the blade was advanced with an orientation of 60 degrees until a quarter of the blade was inside the joint. At this point, the blade was turned 90 degrees to the lateral aspect of the joint to face the adductor tendon (Figure 1B). The adductor tendon was cut with a frontal movement of the blade, while the first toe was being driven into varus (Figure 1C). A click was heard as confirmation of the tendinous release. The ideal resection consisted of the complete detachment of the adductor tendon and the release of the lateral plantar capsule only.

EPLR Technique

A 3-mm incision was made over the first web space at the level of the first MTP joint (Figure 2A). The beaver blade was oriented parallel to the extensor tendon and advanced with an orientation of 45 degrees until contact with the distal part of the lateral sesamoid was achieved (Figure 2B). With an anteroposterior movement, the proximal and superior part of the lateral sesamoid was released (suspensory ligament) (Figure 2C). The blade was then advanced until it reached the proximal phalanx to ensure that the suspensory ligament was released. Next, the beaver blade was repositioned in the initial position, rotated 90 degrees, and introduced into the inferior part of the first MTP joint, under the lateral collateral ligament (LCL) of the first MTP joint.

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1References 1-3, 5, 7, 8, 10, 14, 15-18, 21-23, 26-28, 30, 31, 33, 35, 37, 39, 40.

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Figure 1. Percutaneous adductor tendon release technique. (A) Incision point with 60-degree blade orientation. (B) Blade facing the adductor tendon. (C) Adductor tendon release associated with a varus movement of the first toe.

Figure 2. Extensive percutaneous lateral release technique. (A) Incision point with 45-degree blade orientation. (B) Blade in contact with lateral sesamoid. (C) Blade directed posteriorly to release suspensory ligament. (D) Blade facing the adductor tendon to release it.
With a frontal movement from medial to lateral, the adductor tendon was released, while the first toe was driven into varus (Figure 2D).

**Anatomical Dissection**

After the procedure, all feet were dissected to observe any sectioned structures during the LR. All dissections were performed by an experienced anatomist. First, a superficial dissection was performed. Any injury to neurological structures, specifically the dorsolateral (DL) nerve of the first toe, was considered. Next, dissection was advanced toward the lateral side of the MTP joint to observe the achieved release of the adductor tendon, suspensory ligament, deep transverse intermetatarsal ligament, phalanx-sesamoid ligament (plantar plate), and lateral head of the flexor hallucis brevis. The degree of release of the different structures was marked as follows: 0, intact; 1, one-fourth release; 2, one-half release; 3, three-fourths release; and 4, full release. Any chondral damage to the metatarsal head was inspected and recorded.

**Statistical Analysis**

Comparison of categorical ordinal variables was calculated using the Mann-Whitney U test. For comparison of binary variables, the Fisher exact test for comparisons of proportions was used. Statistical analysis was performed using SPSS (version 11; SPSS, Inc, an IBM Company, Chicago, IL). All tests were 2-tailed, with \( P < .05 \) considered significant.

**Results**

Both techniques demonstrated to be effective in reproducing a MI LR. A satisfactory release of the adductor tendon was achieved equally in both techniques (\( P = .85 \)). The EPLR was successful in releasing additional structures as described (plantar plate, lateral head of FHB, suspensory and intermetatarsal ligament; \( P < .05 \)). One case of inadvertent complete section of the flexor hallucis longus (FHL) was identified in the PATR group (Figure 3) and none in the EPLR group (\( P = .5 \)). No cases of DL nerve injury were seen with either of the techniques.

In contrast to the EPLR, the PATR never released the suspensory ligament, and the LCL was released in 4 cases (36.4%). The plantar plate was partially cut in 4 cases (36.4%), affecting the lateral head of the flexor hallucis brevis also in all 4 cases (36.4%). In addition, in 1 of these cases, the tendon of the flexor hallucis longus was completely sectioned (9%). The adductor tendon was released in all cases (100%) (Table 2 and Figure 4).

No neurological structures (dorsolateral nerve of the first toe and dorsomedial nerve of the second toe) were injured during the MI procedure (Figure 5). No chondral damage to the metatarsal head or injury to the extensor hallucis tendons were observed in any case.

**Table 1.** Description in the Literature of the Released Structures During Minimally Invasive Lateral Release.

<table>
<thead>
<tr>
<th>Article</th>
<th>Structures Claimed to Be Released</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carvalho et al,7 Martinez Nova et al,30 Kurashige et al22</td>
<td>Adductor hallucis tendon</td>
</tr>
<tr>
<td>Biz et al,4 Diaz Fernández,15 Martinez Nova et al,31 Cervi et al,8 Pichierri et al34</td>
<td>Adductor hallucis tendon and partial lateral capsule</td>
</tr>
<tr>
<td>Scala et al15</td>
<td>Phalangeal head of adductor tendon and adherences between lateral sesamoid and plantar side of the capsule</td>
</tr>
<tr>
<td>De Lavigne et al12</td>
<td>Adductor tendon, plantar capsule, and transverse metatarsal ligament</td>
</tr>
<tr>
<td>Lee et al23</td>
<td>Lateral part of the plantar plate and lateral phalangeal-sesamoid ligament</td>
</tr>
<tr>
<td>Gicquel et al18</td>
<td>Lateral phalangeal-sesamoid ligament and both medial and lateral suspensory ligaments</td>
</tr>
<tr>
<td>Jowett et al21</td>
<td>Lateral phalangeal-sesamoid ligament</td>
</tr>
<tr>
<td>Lucas et al,26 Crespo Romero et al,10 Siclari et al,17 Brogan et al6</td>
<td>Not specified during technique description</td>
</tr>
<tr>
<td>Bauer et al,2,3 Di Giorgio et al16</td>
<td>“Abductor” tendon transverse head and capsule</td>
</tr>
</tbody>
</table>

**Discussion**

The most important finding of the study was that the MI LR of the first MTP joint was a safe and reliable technique that was performed in cadavers without damaging any neurovascular structures or articular cartilage. Both the PATR and EPLR techniques aimed to release the adductor tendon, and they were successful in doing so without a significant
difference ($P = .85$). The PATR was successful in achieving a complete release of the tendon, whereas the EPLR achieved a three-fourths release in most of the cases. As described in the technique, the EPLR also aimed to release additional structures (lateral plantar plate, lateral head of FHB, suspensory and intermetatarsal ligaments). As

<table>
<thead>
<tr>
<th>Structure</th>
<th>PATR (n = 11), No. (%)</th>
<th>EPLR (n = 11), No. (%)</th>
<th>$P$ Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adductor tendon</td>
<td>11 (100)$^a$</td>
<td>11 (100) (three-fourths in 91% and one-half in 9%)$^a$</td>
<td>.85</td>
</tr>
<tr>
<td>Lateral part of plantar plate</td>
<td>4 (36.4)$^b$</td>
<td>10 (91)$^a$</td>
<td>&lt;.05</td>
</tr>
<tr>
<td>Lateral head of flexor hallucis brevis</td>
<td>4 (36.4)$^b$</td>
<td>9 (82)$^a$</td>
<td>&lt;.05</td>
</tr>
<tr>
<td>Suspensory ligament</td>
<td>0 (0)$^b$</td>
<td>11 (100)$^a$</td>
<td>&lt;.05</td>
</tr>
<tr>
<td>Intermetatarsal ligament</td>
<td>0 (0)$^b$</td>
<td>11 (100)$^a$</td>
<td>&lt;.05</td>
</tr>
<tr>
<td>Lateral collateral ligament (metatarsophalangeal fascicle)</td>
<td>4 (36.4)$^b$</td>
<td>0 (0)$^b$</td>
<td>&lt;.05</td>
</tr>
<tr>
<td>Flexor hallucis longus</td>
<td>1 (9.09)$^c$</td>
<td>0 (0)$^c$</td>
<td>.5</td>
</tr>
<tr>
<td>Injury to DL nerve</td>
<td>0 (0)$^c$</td>
<td>0 (0)$^c$</td>
<td>NA</td>
</tr>
</tbody>
</table>

Abbreviations: DL, dorsolateral; EPLR, extensive percutaneous lateral release; NA, not applicable; PATR, percutaneous adductor tendon release.

$^a$Structures intended to be released by the specific technique.

$^b$Structures not intended to be released (but may assist in correcting the deformity).

$^c$Structures not intended to be released (and may affect outcomes negatively).
confirmed in our dissections, the EPLR was significantly better at achieving the expected release of these structures when compared to the PATR ($P < .05$). In a small number of cases ($n = 4$), the PATR also inadvertently released the LCL, which was found to be statistically significantly higher than the EPLR ($n = 0$) ($P < .05$). This could be the result of a lateral movement of the blade while being too dorsal to perform an isolated release of the adductor tendon, and therefore a combined adductor tendon and LCL release occurred. Although none of the techniques considers the LCL as part of the structures to be released, it may assist in correcting the deformity without detrimental effects for the patient. Despite having identified a complete section of the FHL due to blade overpenetration in 1 of the PATR cases, this was not considered statistically significant when compared to the EPLR ($P = .5$). Both techniques were able to avoid injury to the DL nerve ($n = 0$).

Anatomy of the lateral aspect of the first MTP joint is complex due to the interconnection of structures around this area. Both the medial and lateral sesamoids are embedded within the plantar plate, to which multiple structures insert. The medial sesamoid receives a contribution from the abductor hallucis tendon and the lateral head of the flexor hallucis brevis; on the other hand, the lateral sesamoid receives a contribution from the transverse and oblique heads of the adductor hallucis and the lateral head of the flexor hallucis brevis. The flexor hallucis longus passes just inferior to the plantar plate (Figure 6). Besides, the collateral ligaments of the first metatarsophalangeal joint reinforce the joint capsule, with insertions that are continuous with the plantar plate, both the metatarso-sesamoid fascicle (suspensory ligament) and the metatarsophalangeal fascicle (Figure 7).

The adductor tendon seems to play an important role in HV, and its release has been suggested in addition to osteotomies to better correct the hallux deformity. In a previous study, Schneider found that the adductor tendon...
had little effect in valgus correction, and the suspensory ligament was the most important structure to section. However, as observed in the current study, after the adductor tenotomy, the valgus of the hallux was completely corrected. This could be explained by the fact that in Schneider’s study, all feet had an “obvious” HV, which presumably was a more severe deformity than the feet used in the present study. Lateral release of both the EPLR and PATR is performed while the first toe is forced into varus, and therefore the surgeon has the ability to assess the degree of correction that is being obtained. If it is considered insufficient, the maneuver can be repeated until sufficient correction is achieved. In this particular case, the EPLR allows for progressive sectioning of the structures, as it includes the release of the sesamoid insertions in addition to the adductor tendon, which could be useful in severe and long-term deformities. These same steps can be added to the PATR if intraoperative assessment requires it. In this study, there were no cases of severe HV, which could explain why in some cases of EPLR, some structures were not fully released (the valgus had already been corrected and therefore the structures were further away from the incision).

The adductor tendon is a plantar structure and therefore difficult to reach from a dorsal approach. Although release of the adductor tendon was achieved in both techniques studied in the present study, the PATR released completely the tendon in most cases as blade penetration at a 60-degree angle to the sole of the foot facilitated reaching the plantar aspect and release of the tendon. In the case of EPLR, the blade penetrates at a 45-degree angle, making it more difficult to reach the plantar aspect of the first MTP joint. As a result, the adductor tendon was never fully released but only partially (three-fourths in 91% and one-half in 9% of cases).

Both the suspensory ligament attached to the lateral sesamoid (metatarso-sesamoid component of the LCL of the first MTP joint) and the transverse metatarsal ligament (between the lateral sesamoid and the plantar plate of the second MTP joint) play an important role in the displacement of the lateral sesamoid off its usual position under the metatarsal head.3,18,21,35 Release of both ligaments is aimed to center the sesamoids under the metatarsal head. The PATR allows releasing the LCL because of the intra-articular blade movement from medial to lateral when necessary. Release of the LCL was found in 4 of 11 cases. On the other hand, the suspensory ligament was never cut, as the incision was distal to it. In contrast to this, the EPLR preserved the LCL in all cases. Due to the obliquity of the blade during EPLR, a more extensive resection at the lateral part of the lateral sesamoid was achieved, including the suspensory ligament (released in 100% of cases), phalanx-sesamoid ligament (plantar plate) (released in 91% of cases), and a complete separation of the attachments of the lateral sesamoid (released in all cases).

Even in the hands of experienced surgeons, inadvertent damage due to blade overpenetration may occur during MI techniques. The adductor tendon and the lateral head of flexor hallucis form a conjoined tendon from the lateral sesamoid to the base of the proximal phalanx. Due to this anatomical feature, an isolated release of only one of them is complex when performing a MI technique.32 The plantar plate and the lateral head of the flexor hallucis brevis were affected in 4 cases when attempting the PATR procedure. Nevertheless, an insignificant clinical effect after this section was observed in the context of HV surgical treatment. In the single case where a complete section of flexor hallucis longus was inadvertently performed during the PATR procedure, the possible clinical effect remains unknown. At the point of the section, the tendon is held by the flexor pulleys, which could avoid retraction of the tendon and therefore favor its healing, but it was definitely an undesired complication.

Despite no direct visualization of the anatomical structures being obtained, both MI techniques were quite accurate in releasing the targeted structures. Our results are similar to those previously reported using a dorsal approach,24 but, surprisingly, open techniques do not show a higher index of accuracy compared to the MI techniques performed in this study. In a comparative study between a transarticular and a medial approach,38 a release of the suspensory ligament and adductor tendon was performed, and assessment of the released structures was conducted after dissection of the specimens. The transarticular technique showed higher accuracy (83%) for both the suspensory ligament and the adductor tendon, while the medial approach release showed low accuracy for the adductor tendon (66%) and very low accuracy for the suspensory ligament (33%). In any case, both techniques proved to be less accurate compared to the MI techniques assessed in the present study. On the other hand, release of lateral structures through a medial transarticular approach demonstrated that the only structure sectioned in all cases was the LCL.11 However, the joint capsule, adductor tendon, and suspensory ligament were only sectioned in 80% of cases,38 and the adductor tendon was released from the lateral sesamoid in 66% of cases,11 showing again a lower accuracy than MI techniques. A thorough knowledge of the local anatomy and exact location of structures is paramount to achieve good results during LR surgery.

In addition, a potential risk of neurovascular injury exists during LR, whether open or MI. Despite the fact that avascular necrosis and open LR have been found to have some correlation,20 arterial injuries were not assessed in the present study as they are believed to play a minor role in MI surgery. Dorsal nerves can be injured when approaching the dorsal aspect of the first MTP joint. Recently, Yañez Arauz et al40 showed that a high risk of nerve injury is present when the LR is made through the dorsal-lateral portal, near the extensor hallucis longus tendon. They observed an average distance between this
dorsal approach and the dorsolateral digital nerve of 0.7 mm. The incision performed during the LR in MI techniques is placed in the first web space, in between branches of the deep peroneal nerve (dorsolateral nerve of the first toe and dorsomedial nerve of the second toe), and no nerve injuries were found in any case.

Limitations of the study include that the feet had different degrees of HV and that not all feet demonstrated an evident deformity. In addition, experienced surgeons performed all the procedures in each group, and a study comparing experienced and novel surgeons in which each surgeon performs both techniques would certainly improve the validity of these results. In addition, a comparative study between percutaneous and open LR would further clarify this subject, as it would help clarify how successful each type of LR is in correcting the deformity.

Conclusion

In conclusion, MI LR for HV was a reliable and accurate technique. In the present study, the lack of direct visualization of the structures being released did not impair the effectiveness of its release. PATR was more effective in fully releasing the adductor tendon, while EPLR released a number of other structures. Therefore, we conclude that MI LR of the first MTP joint for HV treatment is a safe and effective procedure that can be easily performed as an adjunct to both MI or open techniques.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article. ICMJE forms for all authors are available online.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

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