Minimally invasive lateral release for hallux valgus treatment: An anatomical study comparing the safety and efficacy of two techniques.

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. The aim was to study two popular techniques for MI LR in cadavers to subsequently dissect the released anatomical structures.

Methods

22 cadaveric feet were included in the study and allocated into two groups, one for each procedure: one group underwent a MI adductor tendon release (AR), and an extensive percutaneous LR (ER) (adductor tendon, suspensory ligament, phalanx-sesamoid ligament, lateral head of flexor hallucis brevis and deep transverse metatarsal ligament) was performed in the other. 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 ($p=0.85$) being partial in the majority of ER cases and full in the majority of AR cases. The EPLR was successful in releasing the intended additional structures ($p<0.05$). One case of inadvertent complete section of the FHL was identified in the PATR group. No cases of DL nerve injury were seen in neither of the techniques.

Conclusion

Percutaneous lateral release is a reliable, safe and accurate technique. 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.

Keywords: Hallux Disorders, Forefoot Disorders, Minimally Invasive Surgery, Lateral Release.

Evidence level: Not applicable

Introduction.

Hallux valgus (HV) is a common deformity affecting the first toe. Among other factors, soft-tissue structures around the first metatarsophalangeal (MTP) joint are believed to play a role in its ethiology.[32] As a consequence, surgical treatment of HV must address soft-tissue contractures in conjunction with bony realignment.[10,24] 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.[2,3] 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 LR,[6,11,24,36,40] others don't consider LR a necessary gesture for HV correction.[4,13,23,28,38] 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.[1,2,19–21,26,27,29,30,33,34,3,5,7,8,12,14,15,18] It is known that the anatomy of the lateral part of the first MTP joint is complex.[16,35] A release of the lateral part of the first MTP joint including the adductor tendon, the suspensory ligament, and the conjoint tendon of the flexor hallucis brevis and adductor muscles (oblique and transverse portions) has been proposed to correct HV deformity.[5,14,18,34,39] However, surgical techniques aiming to release one or several of the lateral structures of the first MTP joint claim different results with regards to the sectioned structures, with little evidence, especially those performed through a MI approach.[1–3,5,7,8,11–14,18–21,23,25,27,29,30,33,34,36,38,40,41]

The aim of this anatomical study was to identify the released structures after performing a MI technique, and to compare two MI techniques: one aiming to an isolated release of the adductor tendon, and one aiming to release the

suspensory ligament, the adductor tendon and the lateral head of flexor hallucis brevis tendon.

Methods.

The study was conducted at the Anatomy Department of our Institution. IRB approval was obtained (IRB number 00003099).

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 demonstrated a HV deformity of less than 10º or no hallux 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 two groups according to the technique used. Every 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 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. PATR technique was performed by one surgeon while EPLR technique was performed by another surgeon. The surgical techniques were performed under x-ray control in order to verify the blade position. The LR is considered complete when the lateral aspect of the first MTP can be opened while the first toe is driven into varus.

After the procedure, an experienced anatomist dissected all specimens.

Surgical techniques.

PATR technique. A 3mm incision was made on 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° until a quarter of the blade was inside the joint. At this point, the blade was turned 90° 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 should be heard as confirmation of the tendinous release. The ideal resection consists of the complete detachment of the adductor tendon and the release of the lateral plantar capsule only.

EPLR technique. A 3mm 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° until contact with the distal part of the lateral sesamoid was achieved (Figure-2b). With an antero-posterior 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° and introduced into the inferior part of the first MTP joint, under the lateral collateral ligament (LCL) of the first MTP joint. 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 in order 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 nerve of the first toe were considered. Next, dissection was advanced towards 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, ¼ release; 2, ½ release; 3, ¾ release; 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's U test. For comparison of binary variables, the Fisher's exact test for comparisons of proportions was used. Statistical analysis was performed using SPSS (version 11, SPSS Inc., Chicago, IL, USA). All tests were 2-tailed, with a p value of < 0.05 considered as 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 ($p=0.85$). The EPLR was successful in releasing additional structures as described (plantar plate, lateral head of FHB, suspensory and intermetatarsal ligament ($p<0.05$)). One case of inadvertent complete section of the FHL was identified in the PATR group and none in the EPLR group. ($p=0.5$) No cases of DL nerve injury were seen in neither of the techniques.

The EPLR released the adductor tendon partially in all cases (¾ in 91%, and ½ in 9% of cases), fully released the suspensory ligament and the intermetatarsal ligament in all cases (100%). The plantar plate was partially released in all cases but one (91%), and the lateral head of flexor hallucis brevis tendon was partially released in 9 cases (82%), but not released in 2 cases. (Table 2)

In contrast to 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 (9,09%). The adductor tendon was released in all cases (100%). (Table 2) (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-3) No chondral damage to the metatarsal head or injury to the extensor hallucis tendons were observed in any case.

Discussion.

The most important finding of the study was that the MI LR of the first MTP joint is a safe and reliable technique that can be performed in cadavers without damaging any neurovascular structures or articular cartilage.

Both the PATR and EPLR techniques aim to release the adductor tendon and they were successful in doing so without a significant difference ($p=0.85$). The PATR was successful in achieving a complete release of the tendon whereas the EPLR achieved a ¾ release in most of the cases. As described in the technique, the EPLR also aims to release additional structures (lateral plantar plate, lateral head of FHB, suspensory and intermetatarsal ligaments). As confirmed in our dissections the EPLR was significantly better at achieving the expected release of these structures when compared to the PATR ($p<0.05$). In a small number of cases ($n=4$) the PATR also inadvertently released the lateral collateral ligament (LCL) which was found to be statistically significantly higher than the EPLR ($n=0$), ($p<0.05$). This could be the result of a lateral movement of the blade while being too dorsal to perform an isolate release the adductor tendon, and therefore a combined adductor tendon and LCL release was obtained. 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 one of the PATR cases, this was not considered statistically significant when compared to the EPLR ($p=0.5$). Both techniques were equally safe 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.[35] Both the medial and lateral sesamoids are embedded within the plantar plate, to which multiple structures insert. The medial sesamoid receives the contribution of the abductor hallucis tendon, and of the lateral head of the flexor hallucis brevis; on the other hand, the lateral sesamoid receives contribution from the transverse and oblique heads of the adductor hallucis and the lateral head of the flexor hallucis brevis. Flexor hallucis longus passes just inferior to the plantar plate (Figure 7). 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 6).

The adductor tendon seems to play an important role in the HV deformity, and its release has been suggested in addition to bone osteotomies to better correct the hallux deformity.[16] In a previous study, Schneider et al found that the adductor tendon had little effect in valgus correction, and the suspensory ligament was the most important structure to section.[35] However, as observed in the current study, after the adductor tendon 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 are 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 gestures can be added to the PATR if intra-operative 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 lie 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 a blade penetration at a 60º angle to the sole of the foot will facilitate reaching the plantar aspect and release of the tendon. In the case of EPLR, the blade penetrates at a 45° 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 partially (¾ in 91%, and ½ 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 bones off its usual position under the metatarsal head.[5,14,18,34] 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, whenever necessary. Release of the LCL was found in 4 out 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 is 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.[31] 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 is 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 healing of the section, but it is definitively an undesired complication.

Despite no direct visualization of the anatomical structures is obtained, both MI techniques showed a high index of accuracy in releasing the targeted structures. Our results are similar than previously reported using a dorsal

approach,[22] but, surprisingly, open techniques do not show a higher index of accuracy when compared to the MI techniques performed in this study. In a comparative study between a trans-articular and a medial approach[37] 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 trans-articular 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 for the suspensory ligament (33%). In any case, both techniques proved to be less accurate when compared to the MI techniques assessed in the present study. On the other hand, release of lateral structures through a medial trans-articular approach demonstrated that the only structure sectioned in all cases was the LCL[9]. However, the joint capsule, adductor tendon and suspensory ligament were only sectioned in 80% of cases,[37] and the adductor tendon was released from the lateral sesamoid in 66% of cases,[9] 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 during LR, being it open or MI, can occur. Despite the fact that avascular necrosis and open LR have been found to have some correlation,[17] 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 al 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.[41] They observed an average distance between this dorsal approach and the DLDN 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 1st toe and dorsomedial nerve of the 2nd toe), and no nerve injuries have been 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 techniques in each group, and a study comparing experienced and novel surgeons where each surgeon performs both techniques would certainly improve the validity of these techniques. In addition, a comparative study between percutaneous and open LR would further clarify this subject, as it would to perform a biomechanical study of both techniques looking at the results of the LR in correcting the deformity.

Conclusion.

In conclusion, MI LR for HV treatment is a reliable, safe and accurate technique. In the present study, the lack of direct visualization of the structures being released did not impair the effectivity of its release.

PATR showed to be more effective to fully release 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.

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