Distal soft tissue procedure in hallux valgus surgery: biomechanical background and technique

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Received: 22 May 2013 / Accepted: 27 May 2013 / Published online: 3 July 2013
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Abstract The distal soft tissue procedure has evolved into an indispensable additional surgical procedure to increase the corrective effect in hallux valgus surgery. Considering the biomechanical development of hallux valgus deformity, degenerative changes of the soft tissues around the first metatarsophalangeal joint contribute much more to the deformity than changes in the bony structures which can rather be seen as degenerative changes secondary to the deformity. Thus the principles in hallux valgus correction should aim to reverse all pathogenetic steps leading to deformity: release of the contracted lateral soft tissue structures, tightening of the torn-out medial structures and reduction and rebalancing the first metatarsal head onto the sesamoid complex. The scientific discussion over the last decades has clarified the impact of different surgical steps and methods on the efficacy of the lateral release, the risk of creating overcorrection or instability of the joint and the risk of avascular necrosis of the first metatarsal head. According to anatomical and clinical data, a lateral soft tissue release can be combined with a distal metatarsal osteotomy, provided that the osteotomy is performed in a defined safe zone without increasing the risk for avascular necrosis of the first metatarsal head. Transecting the lateral metatarsosesamoid suspensory ligament is the key to a successful lateral release in hallux valgus surgery. Release of the deep transverse metatarsal ligament and the adductor hallucis muscle does not contribute to hallux valgus correction. The lateral short sesamophalangeal ligament and the plantar attachment of the articular capsule should be preserved to avoid possible joint instability. Thus today, the distal soft tissue procedure cannot be seen only as a supplementary surgical procedure in cases where the bony procedure needs additional correction, but rather is an indispensable

procedure to restore the physiological situation and function of the first metatarsophalangeal joint.

Introduction

Today, the distal soft tissue procedure is considered to be an effective additional surgical procedure to increase the corrective effect in hallux valgus surgery. This soft tissue procedure aims to restore the physiological balance of capsular, ligamentous and muscular structures around the first metatarsophalangeal (MTP) joint. During the last decades worldwide scientific discussions, clinical surveys [1–8], anatomical studies [9, 10] and experimental set-ups [11–14] have helped to clarify open questions about soft tissue procedures: is it necessary in every case of bunion surgery and is there a technique superior in respect of high efficiency and low risk? Certain reservations exist regarding the combination of distal soft tissue procedures and distal metatarsal osteotomies. This is based on the assumption of a higher risk of avascular osteonecrosis due to impairment of arterial blood supply by the lateral release [15, 16]. While anatomical studies give guidelines on how to preserve arterial blood supply in distal metatarsal osteotomies [9], disagreement has existed regarding the necessity of single surgical steps to perform an effective and secure lateral release.

The anatomy

From an anatomical point of view [10], the following structures possibly contribute to the tissues involved in a lateral release (Fig. 1):

- **Structures on the lateral side of the first MTP joint:** The *lateral collateral ligament* is a ligamentous reinforcement of the articular capsule running from the lateral tubercle of the metatarsal head to the lateral tubercle of

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Fig. 1 Anatomical structures accessible for a lateral release as part of a distal soft tissue procedure: *AHM* adductor hallucis muscle, *DTL* deep transverse metatarsal ligament, *LCL* lateral collateral ligament, *MSL* lateral metatarsosesamoid suspensory ligament, *PCA* plantar capsular attachment, *SPL* lateral short sesamophalangeal ligament

the base of the proximal phalanx. Another ligamentous reinforcement of the articular capsule—the *lateral metatarsosesamoid suspensory ligament*—runs from the lateral tubercle of the metatarsal head to the lateral border of the lateral sesamoid. The *deep transverse metatarsal ligament* represents a fibrous connection between the lateral sesamoid and the plantar plate of the second MTP joint. The *adductor hallucis muscle* with its variable insertion on the lateral sesamoid and the base of the proximal phalanx arises by two heads: an oblique head originating from the proximal ends of the middle three metatarsal bones and a transverse head coming from MTP ligaments of the lateral three toes.

- **Structures on the plantar aspect of the first MTP joint:** Two ligamentous structures connect the distal parts of the medial and the lateral sesamoid with the base of the proximal phalanx. These two ligaments, called *lateral and medial short sesamophalangeal ligaments*, are the distal attachment of both heads of the flexor hallucis brevis muscle after interposition of the sesamoids. The proximal *plantar attachment of the articular capsule* plays an important role in the metatarsal head blood supply. The tendon of the *flexor hallucis longus muscle* runs in a groove between the medial and lateral sesamoid. The *plantar aponeurosis*, playing an important role in stabilising the first ray, inserts into the articular capsule and the base of the proximal phalanx.
- **The structures on the medial side** of the joint appear similar to the anatomy of the lateral side, especially the V-shaped ligamentous reinforcements, constituting the *medial MTP ligament* and the *medial metatarsosesamoid ligament*. The *abductor hallucis muscle* arises from the medial process of the tuberosity of the calcaneus, from the lacinate ligament, from the plantar aponeurosis and the intermuscular septum and ends in the medial plantar part of the first MTP articular capsule.
- **Structures on the dorsal side of the first MTP joint** are the *tendons of the long and the short extensor muscles*

with the tendon of the extensor hallucis brevis muscle running laterally, inserting at the dorsal proximal aspect of the proximal phalanx, and the tendon of the extensor hallucis longus muscle running medially inserting into the base of the distal phalanx of the great toe. The *dorsal part of the articular capsule* presents as a soft tissue structure.

The role of soft tissues in the development of hallux valgus deformity

The metatarsal head shifts medially, losing its position and guidance on top of the medial and lateral sesamoids (Fig. 2). This leads to elongation of the medial ligamentous and capsular structures and consequently to shortening of the lateral soft tissue structures. This imbalance between medial and lateral soft tissue structures can be seen on plain dorsoplantar radiographs: Development of an incongruous joint with shortening of the distance corresponding to the lateral collateral ligament and respective lengthening of the medial collateral ligament (Fig. 3). The shortening of the lateral suspensory ligament corresponds to the “sesamoid luxation” seen on plain dorsoplantar radiographs and on anatomical cross-sectional views together with an elongation of the medial metatarsosesamoid ligament. A radiographic skyline view of the joint gives an impression of this metatarsosesamoid luxation (Fig. 4).

It is noteworthy that the sesamoid apparatus generally remains in place during development of hallux valgus deformity, while the distance between the lateral sesamoid and the second metatarsal head remains fairly constant [corresponding to an unaltered length of the deep intermetatarsal (IM) ligament]. It is the metatarsal head that shifts laterally, and this implicates the necessity of repositioning the metatarsal head onto the sesamoids—and not repositioning the sesamoids down under the displaced metatarsal head.

Apart from these aforementioned degenerative changes of soft tissues during development of hallux valgus deformities, bony changes around the first ray are of minor importance and in general of degenerative character as a consequence of the deformity: degeneration of the first MTP joint due to deformity or instability and especially degeneration and deformation of the articulation between the plantar aspect of the first MTP head and the sesamoid apparatus (see Fig. 2, right).

This preponderance of soft tissue changes in hallux valgus deformity implicates the importance of distal soft tissue procedures for correction of the deformity. Concentrating on the first step of the distal soft tissue procedure—the lateral release—necessity, efficiency and possible biomechanical risk of dividing one of these structures is judged controversial. Generally, the purpose of the lateral release in combination with a

Fig. 2 Anatomical cross section at level of first MTP head and sesamoid apparatus. *Left* correct alignment of first MTP joint—first metatarsal head is centred on the sesamoid apparatus, with each sesamoid running in its groove. *Right* hallux valgus deformity—first MTP head shifted medially, with the medial sesamoid now in former place of the

lateral sesamoid. The lateral sesamoid shifted into the space between first and second metatarsal heads. The deep intermetatarsal transverse ligament unchanged in length. (Courtesy of Professor E. Brenner, Division of Clinical and Functional Anatomy, Department of Anatomy, Medical University Innsbruck, Austria)

medial capsular reefing is to realign the metatarsosesamoid complex to decrease the first IM angle and to correct the hallux valgus deformity. Insufficient lateral release will lead to primary undercorrection or increased risk of recurrence of the deformity. On the other hand, improper or excessive soft tissue procedures may lead to overcorrection, instability and avascular necrosis. In general, the terms “distal soft tissue procedure” or “lateral release” need a clear definition: Various authors subsume completely different combinations of the above-mentioned single surgical steps under the expression distal soft tissue procedure or lateral release [7, 17–19].

The exact description of distal soft tissue procedure is very inconsistent: Mann and Coughlin [17] describe primarily a transection of the deep metatarsal ligament in combination with sparing perforations of the lateral articular capsule. Resch et al. [18] release the attachment of the adductor hallucis muscle. Schneider et al. [7] open the articular capsule by dividing the lateral collateral ligament and then transecting the shortened lateral metatarsosesamoid suspensory ligament. Thomas et al. [19], among other surgical steps, release the lateral head of the flexor hallucis brevis muscle via lateral sesamoidectomy, thus dividing the lateral short sesamophalangeal ligament.

Performing the correct distal soft tissue procedure

Osteotomies of the first metatarsal are the basis of the vast majority of hallux valgus repair procedures, with the osteotomy level depending on the degree of deformity. But as mentioned before, it is the soft tissues that are altered during the development of hallux valgus deformity; changes in bony structures occur only as a degenerative response accelerated by the deformity. So in nearly all types of bony

Fig. 3 Typical radiographic pattern of hallux valgus deformity showing shortening of lateral collateral ligament (LCL) and elongation of medial collateral ligament (MCL). Sesamoid luxation corresponds to shortening of lateral metatarsosesamoid ligament and elongation of medial metatarsosesamoid ligament

Fig. 4 Radiographic skyline view of first MTP joint demonstrating metatarsosesamoid luxation with concomitant shortening of lateral metatarsosesamoid ligament

correction, a distal soft tissue is of major importance to guarantee the corrective effect and to decrease the risk of recurrence of the deformity.

The lateral release: necessity, efficiency and possible biomechanical risk of dividing different anatomical structures

The following conclusions mainly were deduced using an experimental set-up simulating different steps of lateral release in different order [14], corresponding to different techniques of lateral release during hallux valgus surgery.

Transecting the *deep metatarsal ligament* has only a limited effect on MTP and IM angles. Regarding sesamoid luxation, the transection of the deep metatarsal ligament leads to overcorrection with medial displacement of the sesamoids.

Releasing the *attachment of the adductor hallucis muscle* has a negligible effect on MTP and IM angles. This insufficient effect has already been reported in a clinical comparison [18]. A release of the adductor hallucis has no effect on sesamoid luxation.

Transection of the *lateral collateral ligament* leads to a limited and insufficient correction of MTP and IM angles. This step as a single procedure has no effect on sesamoid luxation. Despite its insufficient effect, this part of the procedure is harmless when it is needed to open the lateral articular capsule for further surgical steps: Neither does this ligament play a role in metatarsal blood supply [9, 10], nor does transection of the ligament lead to instability of the joint.

The *lateral metatarsosesamoid suspensory ligament* is the key to a successful lateral release [8, 14, 20]: Corrections of MTP and IM angles to physiological values are achieved only when the ligamentous connection between the metatarsal head and the lateral sesamoid is transected completely. At the same time, reduction of sesamoid luxation is only possible when the lateral metatarsosesamoid suspensory ligament is transected. As this ligament is part of the lateral articular capsule, it only can be exposed by incising the capsule (Fig. 5). On the one hand the ligament must be transected completely to guarantee the expected effect, on the other hand the plantar and proximal attachment of the articular capsule must be preserved to avoid disturbances of vascular supply to the metatarsal head [9, 10].

The *lateral short sesamophalangeal ligament* should not be incised during the soft tissue procedure, as this leads to overcorrection of the MTP angle and instability of the joint. This fibrous connection of the lateral sesamoid and the base of the proximal phalanx represents the lateral head of the flexor hallucis brevis muscle and should not be touched during joint-preserving hallux surgery. The IM angle is not influenced by transection of the lateral short sesamophalangeal ligament; the sesamoid luxation will be overcorrected with the risk of medial

Fig. 5 Using a single dorsomedial skin incision, lateral release is done under direct visualisation: first web space is exposed using two Farabeuf retractors, the articular capsule is opened by transection of the lateral collateral ligament, a right-angled forceps is introduced into the joint and the lateral metatarsosesamoid ligament is released

subluxation of the medial sesamoid. These experimental data correlate with the clinical results of Thomas et al. [19], reporting a risk of overcorrection after dissection of the lateral short sesamophalangeal ligament by lateral sesamoidectomy.

Detachment of the *plantar articular capsule* will result in an overcorrection of the deformity. This step should be avoided in any distal metatarsal osteotomy to preserve arterial blood supply and thus to minimise the risk of avascular necrosis of the metatarsal head [9].

Medial capsular repair

Once the contracted lateral structures are released and any osteotomy is done, medial capsular repair completes the hallux valgus correction. Equivalent to release on the lateral side, medial capsular repair aims to restore a physiological ligamentous situation on the medial side. This means that formerly elongated medial metatarsosesamoid ligament and medial collateral ligament must be shortened. The first and most important step is a suture that follows the medial metatarsosesamoid ligament and repositions the metatarsal head back onto the sesamoid apparatus (Fig. 6). This rebalancing of the metatarsosesamoid joint corrects the first IM angle, normally hallux valgus angle too, so that a suture following the medial collateral ligament only serves to hold the already accomplished correction.

Surgical approach for the lateral release: single incision, double incision or transarticular approach?

The decision for single or double incision technique depends mainly on the personal preference of the surgeon: While a *single dorsomedial incision* helps to decrease the overall

Fig. 6 Medial capsular repair is accomplished using a U-shaped suture that follows the direction of former medial metatarsosesamoid ligament, repositioning the metatarsal head onto the sesamoid apparatus

length of the skin incision and gives an excellent exposure of the lateral capsule, it carries a certain risk for the dorsomedial neurovascular bundle. Careful dissection provided, damage to the neurovascular bundle can be avoided. This potential risk can be avoided completely by a *double incision* technique—one medial incision for the bony procedure and the medial capsular repair and one via the first web space for the lateral release. In contrast to these two outside-in-techniques, an inside-out *transarticular approach* [1, 21] can be used for releasing the lateral structures. But according to anatomical studies, a transarticular approach bears the risk of incomplete transection of the ligament, damage to the articular cartilage and damage of neurovascular structures in the first web space [22]. When these steps of lateral release are performed transarticularly, special attention must be paid to avoid damage to these IM structures [22]. If not very familiar with the transarticular approach, the release is best performed under direct visualisation via the first web space [7, 14] (Fig. 5).

Lateral release: a risk for metatarsal head blood supply?

During development and initial spread of distal metatarsal osteotomies, especially the chevron-type osteotomies, many authors [16, 23–25] warned against the combination of distal metatarsal osteotomies with a lateral distal release for fear of major disturbance of metatarsal head blood supply with the risk of osteonecrosis. Steinböck [26] was the first to routinely combine the Austin osteotomy with a distal soft tissue procedure without increased risk of osteonecrosis of the metatarsal head. Anatomical studies [9] have confirmed the possibility of a safe combination of distal metatarsal osteotomy with lateral release, provided that the osteotomy is performed in a “safe zone”, followed by clinical studies confirming the risk free combination of soft tissue procedure

and osteotomy [5, 7, 27–30]. Additionally, the blood supply into the metatarsal head via plantar and dorsal capsular attachment should be left intact. Today, most surgeons combine distal metatarsal osteotomies with a distal lateral release and metatarsal head osteonecrosis remains an extremely rare complication in the literature.

How to avoid undercorrection?

Any lateral soft tissue structure remaining contracted at the end of surgery may impede correction of the deformity in terms of repositioning the metatarsal head onto the sesamoid apparatus with resulting undercorrection of IM and MTP angles. During most bunion corrections, dissection of the lateral metatarso-sesamoid suspensory ligament will be the key to a successful lateral release after incision of the lateral articular capsule and the lateral collateral ligament. After this step, the correct and complete release must be checked by forcing the toe into overcorrection, a procedure that helps to release remaining contracted fibres of lateral contracted tissues. If this manoeuvre fails to correct or slightly overcorrect the deformity, the surgeon should ensure that all contracted structures have been released. A surgical approach via the first web space helps to correctly assess all other structures by direct view—in contrast to the limited visibility of all lateral structures using a transarticular approach. Together with a medial capsular repair, this defined procedure allows correction of MTP and IM angles as well as sesamoid luxation. This rebalancing of the metatarso-sesamoid joint complex is essential, as failure to reduce the sesamoids has been identified as a risk factor for recurrence of hallux valgus deformity [31] (Fig. 7).

Dissection of the deep transverse metatarsal ligament would facilitate correction of sesamoid luxation with easier correction of the MTP angle. But this surgical step disrupts the connection between the sesamoid apparatus and the lesser metatarsal leading to an unchanged or even increased first IM angle, as medial capsular repair will pull the sesamoids under the displaced first MTP head rather than reposition the MTP head onto the sesamoids in their correct position. So undercorrection of first IM angle must be avoided by maintaining the deep transverse ligament.

How to avoid overcorrection?

The aim of any distal soft tissue procedure in hallux valgus correction is to rebalance the medial and lateral soft tissue structures around the first MTP joint. Thus both excessive release on the lateral side and excessive tightening of the medial structures must be avoided. In detail, the lateral short sesamophalangeal ligament which is the ligamentous connection between the lateral sesamoid and the lateral part of the base of the proximal phalanx should be preserved. The

Fig. 7 *Left* undercorrection following chevron osteotomy with inadequate lateral release. First metatarsal head was not repositioned onto the sesamoid apparatus due to insufficient release of contracted lateral metatarsosesamoid ligament—sesamoid luxation grade 3 remained unchanged in relation to preoperative situation. *Right* after revision surgery with correct release of lateral metatarsosesamoid ligament the first MTP head is correctly relocated onto the sesamoid apparatus, resulting in normalisation of IM and MTP angles and sesamoid luxation

same applies to lateral sesamoidectomy. With these procedures, the joint completely loses its lateral stabilisers and any excess of medial capsular reefing will result in uncontrollable varus deviation of the phalanx. Caution should be exercised in releasing an isolated insertion of the adductor tendon from the base of the proximal phalanx of the great toe since it may actually represent the conjoined insertion of the lateral flexor hallucis brevis tendon and the adductor tendon [32]. In cases of incomplete lateral release with risk of undercorrection, where visual and manual inspection suggest additionally releasing soft tissues at the planter lateral part of the proximal phalanx, this must be done stepwise with extreme care, as this gradual release touches the lateral sesamophalangeal ligament with the risk of instantly converting undercorrection into overcorrection. In any event, a procedure such as this may be necessary in cases of extreme hallux valgus angles. The plantar attachment of the articular capsule should be preserved not only as the last stabiliser of the joint, but mainly because of its predominant role in blood supply.

Efficacy of the lateral release: an explanation of contradictory results in the literature

In the light of the aforementioned experimental findings, the contradictory results in the literature—describing a lateral release as ineffective [18], necessary for an adequate correction [7] or dangerous in terms of overcorrection [19]—can be explained without difficulty. A lateral release will remain ineffective, as long the key ligament—the lateral

metatarso-sesamoid ligament—is not released [18]. On the contrary, a lateral release will have a high risk of overcorrection, if the main lateral stabilisation is removed by excising the lateral sesamoid [19]. These examples stress the necessity of an exact definition of a distal soft tissue procedure, which is often neglected in the literature.

Conclusion

Due to the pathomechanical significance of the soft tissues during development of hallux valgus deformity, a distal soft tissue procedure should be part of all bunion surgery to realign the joint. Only in cases of radical bony procedures such as fusion of the first MTP joint or in very select cases with minor deformities with less impact of soft tissue structures will the bony procedure alone be sufficient to correct the deformity.

In principle, contracted structures on the lateral side of the joint must be released, worn out structures on the medial side must be tightened, reducing and rebalancing the metatarsosesamoid joint complex. In most cases, the bony procedure increases and completes the correction, with the site of osteotomy depending on the degree of deformity.

The lateral metatarso-sesamoid suspensory ligament is the key to a successful lateral release in hallux valgus surgery. This has been proven experimentally [11, 12, 14] and clinically [7, 20, 27]. Preferably this ligament should be transected under direct vision after incision of the lateral

articular capsule and the lateral collateral ligament. Together with a medial capsular repair, this procedure allows correction of MTP and IM angles as well as sesamoid luxation. Transection of the deep transverse metatarsal ligament and the attachment of the adductor hallucis muscle had virtually no corrective effect. The lateral short sesamophalangeal ligament and the plantar attachment of the articular capsule should be preserved, as their transection leads to overcorrection and instability of the joint.

An effective and safe lateral release must include the following surgical steps: The capsule should be opened by transecting the contracted lateral collateral ligament. The lateral metatarso-sesamoid suspensory ligament must be identified and transected completely under direct vision. This procedure leaves the dorsal and plantar capsular attachment, the deep transverse metatarsal ligament and the attachment of the adductor hallucis muscle completely intact.

Acknowledgments The author would like to thank Professor E. Brenner, Division of Clinical and Functional Anatomy, Department of Anatomy, Medical University Innsbruck, Austria, for permission to use photographs of anatomical dissections.

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