Foot and Ankle Surgery 25 (2019) 684–690

Contents lists available at ScienceDirect

Foot and Ankle Surgery

journal homepage: www.elsevier.com/locate/fas

A meta-analysis of comparative clinical studies of isolated osteotomy versus osteotomy with lateral soft tissue release in treating hallux valgus

Kaissar Yammine[a,b,*], Chahine Assi[a]

[a] Lebanese American University Medical Center-Rizk Hospital, Department of Orthopedics, Achrafieh, Beirut, Lebanon and Lebanese American University School of Medicine, Byblos, Lebanon
[b] Center for Evidence-Based Anatomy, Sports & Orthopedic Research, Beirut, Lebanon

ARTICLE INFO

Article history:
Received 7 May 2018
Received in revised form 2 July 2018
Accepted 20 August 2018

Keywords:
Hallux valgus
Chevron osteotomy
Lateral soft tissue release
Adductor hallucis
Lateral sesamoido-metatarsal ligament

ABSTRACT

Background: Contradictory results have been reported in the literature over the beneficial effect of the lateral soft tissue release (LSTR) when associated to an osteotomy for the treatment of hallux valgus (HV).
Materials and methods: Six comparative studies totalizing 425 patients (549 feet) were computed and comparing two groups: one group of patients having osteotomy alone and the other group having osteotomy with LSTR.
Results: Subgroup analysis in relation to the type of LSTR yielded significant better HVA correction ($P < 0.0001$) in favor of those reporting the release of the lateral sesamoido-metatarsal ligament (LSML). A moderate significance ($P = 0.03$) of the inter-metatarsal angle (IMA) difference was found in favor of LSTR.
Conclusions: There could be a beneficial effect of transecting LSML in all cases of HV deformity, and a probable efficacy of an added adductor hallucis tendon transection when the deformity is moderate to severe.

1. Introduction

Hallux valgus (HV) is one of the most common deformities of the foot. The deformity combines a lateral deviation of the great toe and a medial deviation of the first metatarsal bone [1]. More than a hundred techniques were described for surgical correction [2]. The array of bone procedures includes proximal and distal metatarsal osteotomies, proximal phalanx osteotomy and arthrodesis of the first metatarso-cuneiform joint. The HV deformity also induces a medial displacement of the first metatarsal head in relation to the sesamoids; it has been demonstrated that the amount of displacement highly correlates with the severity of the HV [3]. Soft tissue procedures, named lateral soft tissue release (LSTR), have been proposed to release the soft tissue structures that are thought to be incriminated in the HV deviation and to bring the sesamoids beneath the metatarsal head. The combination of soft tissue procedures and osteotomies is believed to better reduce hallucal sesamoids in their anatomical position and to maintain a long-term correction [4,5].

Distal osteotomies, such as the Chevron and Scarf, are very common in treating HV. The reported variants of these osteotomies mainly attempted to confer better stability with fewer complications. However, the lateral translation of the metatarsal head offered by such osteotomies is thought by many to yield a suboptimal HV angle correction [6,7]. On the other hand, under the label of LSTR, the soft tissue structures involved in the release vary widely between authors. While some authors consider the tenotomy of the phalangeal conjoint tendon of the adductor hallucis (AddH) as a sufficient procedure for an optimal release [8], three other structures are commonly transected when performing LSTR: the lateral capsule of the first metatarso-phalangeal joint (MTPJ), the sesamoid suspensory ligament or lateral sesamoid metatarsal ligament (LSML), and the transverse metatarsal ligament (TML) (Fig. 1). One or more of these three structures could be combined to the AddH tenotomy when performing the LSTR. It is generally accepted that if lateral release is not performed the risk of recurrence is increased [9,10]. However, its efficacy in reducing the hallux valgus deformity is not well known. Several authors have identified that incomplete postoperative reduction of the sesamoids is a potential risk factor for recurrence after proximal metatarsal osteotomy [11–13]. When combined to a Chevron, the benefit of the LSTR has been questioned by some reports [14–16] while others demonstarted significant better correction

* Corresponding author at: Lebanese American University Medical Center-Rizk Hospital, Department of Orthopedics, Achrafieh, Beirut, Lebanon.
E-mail address: cesar.yammine@laumcrh.com (K. Yammine).

https://doi.org/10.1016/j.fas.2018.08.009
1268-7731/

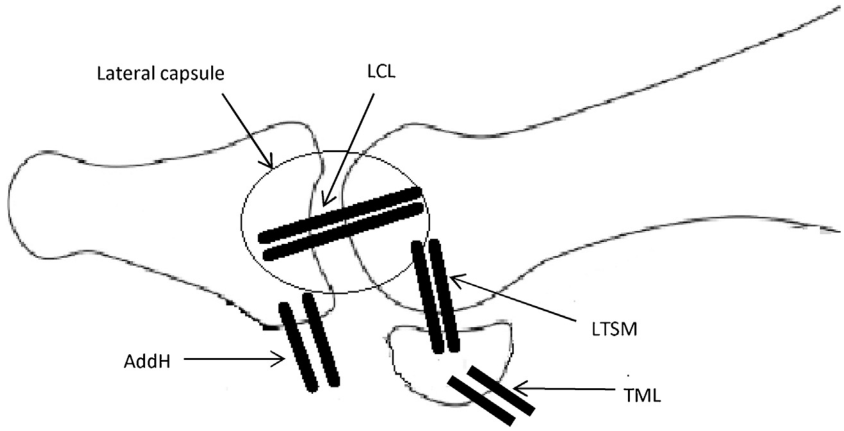

Fig. 1. Anatomical structures involved in lateral release. LCL: lateral collateral ligament, AddH: auctor halluces, LTSM: lateral sesamoido-metatarsal ligament, TML: transverse metatarsal ligament.

and long-term results [6,7]. Augoyard et al. [16] demonstrated that more than 50% of their patients who presented with a severe preoperative hallux valgus deformity (HVA >30° or IMA >9°) were not reduced after full release.

Woo et al. [17] stated that although there were significantly improved clinical and radiologic outcomes after surgery, the LSTR procedure did not result in medial shift or reduction of the sesamoid position. Lamo-Espinosa et al. [18] suggested that dislocation of the sesamoid complex is actually caused by displacement of the first metatarsal. They concluded that the scarf–akin osteotomy adequately restores the sesamoid apparatus beneath the first metatarsal head without direct plantar-lateral soft tissue release.

Such contradictory results over the role of LSTR in the correction of HV deformity are source of confusion. The literature lacks an evidence synthesis over the benefit of a LSTR and on which structure(s), if any, should be transected in order to restore the axis of the big toe.

Therefore, the aim of this meta-analysis (MA) is to quantify and compare the effect size of HV correction in patients having an osteotomy versus those having LSTR combined to the osteotomy. It also investigates which of the lateral structures has an impact on HV correction.

2. Methods

A search strategy was developed using the following electronic databases: PubMed, Embase, SciELO, Cochrane, and Google Scholar from inception till the first of February 2018. Broad Boolean terms were used to locate the maximum number of relevant studies: ("hallux valgus" AND lateral AND release). The primary outcome is set to be the hallux valgus angle (HVA) correction. Secondary outcomes were defined as the inter-metatarsal angle (IMA) correction, the post-operative tibial sesamoid position, the distance of the fibular sesamoid to the second metatarsal head, the American Orthopedic Foot & Ankle score (AOFAS) difference, and the complications.

The inclusion criteria comprise: (a) studies of comparative design, (b) the use of the same osteotomy type in both treatment arms and, (c) the report of the primary outcome. Exclusion criteria were the all non-comparative study design, the comparison of different osteotomies within a study, re-do surgeries, and the absence of reporting the primary outcome.

2.1. Statistical analysis

Statistical analysis was performed using the StatsDirect software. Effect size meta-analysis (MA) was used to detect weighted mean differences (d) between interventions. Proportion MA was used to calculate the weighted frequency of complications. Heterogeneity was assessed using the inconsistency test (I^2). Whenever the I^2 statistic had a value of more than 50%, a random-effects model estimate was reported, otherwise the fixed-effects estimate was chosen. Subgroup MA was performed in relation to the study design of the included studies and in relation to the type of lateral release. Significance of the difference between pre-operative angles, correction of AOFAS scores and the prevalence of complication between both interventions was conducted using the unpaired t-test.

3. Results

3.1. Search results

The electronic search yielded 112 records. Ninety-nine abstracts were screened and 13 duplicates were removed. Full manuscripts of eleven potentially relevant papers were retrieved. Five papers were retained after applying the inclusion criteria. Reference checking yielded one additional relevant paper. In total, six papers comprising 425 patients (549 feet) were included in the meta-analysis (Fig. 2). Two papers used a sort of randomization while the other four were of retrospective comparative design (Table 1).

3.2. Baseline data results

The mean age of the subjects was 50.3 ± 4.8 years. The mean follow-up was 20.4 ± 9.6 months. The osteotomy group (named non-LSTR group) comprises 234 patients (280 feet) while the combined (osteotomy + LSTR) group (named LSTR group) totalized 219 patients (261 feet). The type of osteotomy was chevron in 5 studies and chevron + Akin in 1 study. Baseline data and the different released structures in each study are shown in Table 1. All patients of the LSTR group had an open release via a dorsal approach of the first webspace. When reported, the tibial sesamoid position was evaluated by the Hardy and Clapham method [3].

The majority of the HV deformity cases are of moderate form on the Manchester scale [19]. The preoperative mean HVA and IMA of

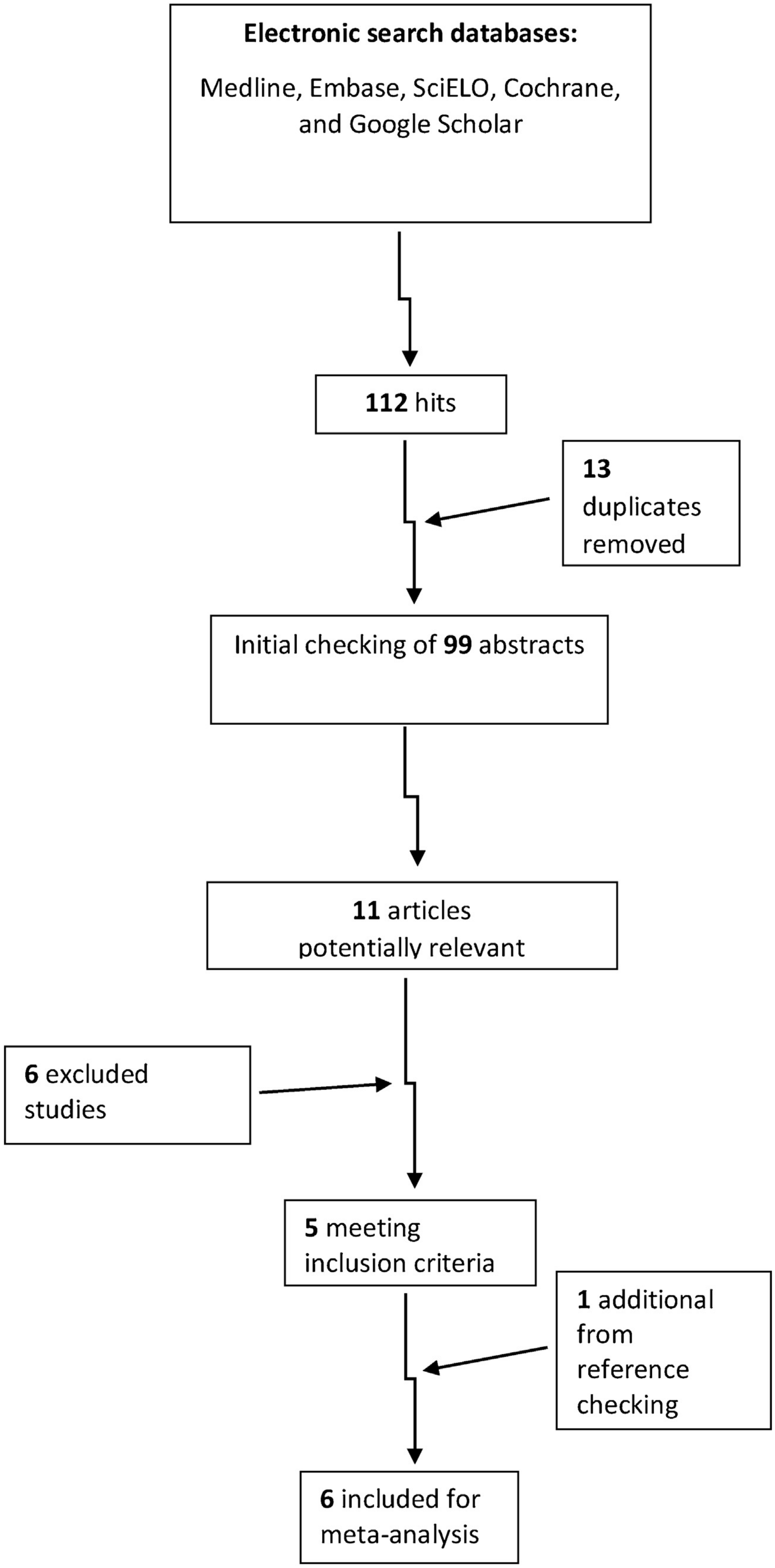

Fig. 2. Flowchart of search strategy.

Table 1
Characteristics of included studies.

Studies	Study design	Sample size (patients/feet)	Age (years)	Follow-up (months)	Type of osteotomy	Released structures of LSTR	Osteotomy only (feet)	Osteotomy + LSTR (feet)
Resch et al. [8]	Randomized	87/106	47 (15–74)	36 (12–48)	Chevron	AddHT	62	44
Trnka et al. [7]	Retrospective comparative	45/48	51.7 (20–82)	17 (12–26)	Chevron	AddHT, lateral capsule, TML	20	28
Lee et al. [14]	Quasi-randomized	86/144	43 (18–48)	22.8 (12–37.2)	Chevron	AddHT, lateral capsule, TML, LSMT	70	74
Woo et al. [17]	Retrospective comparative	90/119	53 (19–81)	9.6 (3.6–22.2)	Chevron +Akin (92.4%) Chevron only (7.6%)	AddHT, lateral capsule, LSMT	68	51
Shi et al. [15]	Retrospective comparative	76 patients/feet	50.4 (18–70)	12	Chevron	AddHT, perforation lateral capsule, TML	35	41
Grle et al. [6]	Retrospective comparative	41/48	57 (43–77)	24 (6–40.8)	Chevron	AddHT, lateral capsule, TML	25	23

AddHT: adductor hallucis tendon (both heads), TML: transverse metatarsal Ligament, LSMT: lateral sesamoid metatarsal ligament.

the non-LSTR group were of 31.4 ± 4.2° and 14.6 ± 1.8°, respectively. The pre-operative mean HVA and IMA of the LSTR were of 31.4 ± 2.8° and 14.7 ± 1.0°, respectively. There were no significant differences in terms of age and gender between both groups ($P < 0.05$). No significance was found in pre-operative HVA and IMA values between both groups ($P = 0.9$). Outcomes and complications reported in each study are shown in Table 2 and Table 3, respectively.

3.3. HVA correction

All studies were amenable to complete data extraction to compute an effect size MA totalizing 541 feet yielding a difference $d = -0.08$ (95% CI = −0.741 to 0.569, $I^2 = 92.5\%$, $P = 0.8$).

Subgroup analysis in relation to study design showed no difference of HVA in RCT studies when compared to retrospective comparative studies ($P = 0.1$) (Table 4).

When comparing the association of AddHT with LSML to AddHT alone, subgroup analysis yielded significant HVA correction difference in favor of the former group ($P < 0.0001$) (Table 4).

3.4. IMA correction

Five studies [6,7,14,16,17] were amenable to complete data extraction to compute an effect size MA totalizing 369 feet yielding a difference $d = -0.11$ (95% CI = −0.446 to 0.211, $I^2 = 63.8\%$, $P = 0.4$).

When studies reporting no TML transection are excluded, such as that of Woo et al. [18], a total of 316 feet yield better correction in favor of LSTR transection ($P = 0.03$) (Table 4).

Subgroup analyses yielded no significant IMA correction difference in relation to study design or to the role of LSML release ($P < 0.05$) (Table 4).

3.5. Sesamoid position

No significant difference was found in the pre-operative tibial sesamoid position scores between both groups ($P = 0.6$). Four studies [6,7,17,18] reported the p operative tibial sesamoid position values totalizing 281 feet yielding a difference $d = 1.93$ (95% CI = 0.945–2.927, $I^2 = 91\%$, $P = 0.0001$), which is in favor of the LSTR group. It was not possible to investigate the role of the LSML since

Table 2
Outcomes.

Studies	HVA Correction w/out LSTR	HVA Correction with LSTR	IMA correction w/out LSTR	IMA correction with LSTR	Post-operative TSP w/out LSTR	Post-operative TSP with LSTR	Diff AOFAS w/out LSTR	Diff AOFAS with LSTR
Resch et al. [8]	7.5 ± 2.27	9.8 ± 2.3°	3°	3°	–	–	–	–
Trnka et al. [7]	16 ± 5°	21 ± 4.5°	8 ± 3°	9 ± 3°	1.1 ± 0.3	0.6 ± 0.2	95 (post-op)	95 (post-op)
Lee et al. [14]	23 ± 4°	20 ± 5°	3 ± 2.5°	4 + 1.25°	–	–	47	43
Woo et al. [17]	8.9 ± 6.5°	3.8 ± 8.7°	6.3 ± 2.9°	5.4 ± 3.1°	4.1 ± 1.25	3.7 ± 1	22.1	28
Shi et al. [15]	12.9 ± 7.9°	15.7 ± 7.1°	5.3 ± 2.6°	5.4 ± 2.0°	3.1 ± 0.9	2.7 ± 1	–	–
Grle et al. [6]	26.84 ± 7.7	23.44 ± 5.4	7.36 ± 3.2°	7.39 ± 1.6°	1.8 ± 0.8	0.8 ± 0.15	92.8 (post-op)	96 (post-op)

LSTR: lateral soft tissue release, LSMT: lateral sesamoid metatarsal ligament, TSP: tibial sesamoid position.

Table 3
Complications.

Studies	Recurrence w/out LSTR	Recurrence with LSTR	Hallux varus w/out LSTR	Hallux varus with LSTR	Other complications w /out LSTR	Other complications with LSTR
Resch et al. [8]	2	1	0	0	–	–
Trnka et al. [7]	0	0	2	1	–	1AVN
Lee et al. [14]	8	7	0	0	2 MTPJ stiffness	1 MTPJ arthritis
Woo et al. [17]	0	0	0	3	–	–
Shi et al. [15]	2	2	0	0	–	–
Grle et al. [6]	0	0	0	0	–	–

LSTR: lateral soft tissue release, MTPJ: metatarso-phalangeal joint.

Table 4
Subgroup meta-analyses.

Variable	Subgroups			
	Type of design		Type of release	
	RCT [studies]	Retrospective comparative [studies]	Including LSMT [studies]	Excluding LSMT [studies]
HVA	d = 0.11 (95% CI = −0.922 to 1.149) I^2 = 95.7% P = 0.8	d = −0.29 (95% CI = −1.110 to 0.513) I^2 = 85 P = 0.8	d+ = 0.66 (95% CI = 0.415 to 0.914) I^2 = 0% P < 0.0001	d = −0.48 (95% CI = −1.149 to 0.178) I^2 = 85.6% P = 0.15
IMA	d = −0.10 (95% CI = −0.898 to 0.682) I^2 = 90.3% P = 0.8	d = −0.11 (95% CI = −0.412 to 0.189) I^2 = 0% P = 0.4	d = −0.10 (95% CI = −0.898 to 0.682) I^2 = 90.3% P = 0.8	d = −0.11 (95% CI = −0.412 to 0.189) I^2 = 0% P = 0.4

LSMT: lateral sesamoid metatarsal ligament.

the study of Lee et al. [14] did not report the sesamoid position outcome.

Only the study of Woo et al. [17] reported the change of the distance of the fibular sesamoid to the second metatarsal head. These measurements decreased postoperatively by 1.9 (±1.1) mm in the LSTR group and 1.6 (±1.1) mm in the non-LSTR group (P = 0.23).

3.6. AOFAS difference

Two studies [7,14] reported the difference between pre- and post-operative AOFAS scores; no significance was found between AOFAS score differences (p = 0.8). Two studies [6,8] reported only the post-operative AOFAS score with no significance using the unpaired t-test (P = 0.5).

3.7. Range of motion

Lee et al. [14] reported significant lower post-operative range of motion in the LSTR group whereas Resch et al. [8] failed to find such. Woo et al. [17] reported 2 cases of joint stiffness in the non-LSTR group.

3.8. Complications

3.8.1. Recurrence

In the non-LSTR group, proportion MA yielded a value of 4% (95% CI = 0.006–0.108, I^2 = 73.5%) over a mean follow-up period of 22.5 ± 10.4 months.

In the LSTR group, proportion MA yielded a value of 3.8% (95% CI = 0.007–0.091, I^2 = 64.2%) over a mean follow-up period of 16.2 ± 9.3 months.

No significance was found between both rate of recurrence (P = 0.8).

3.8.2. Hallux varus deformity

The mean follow-up periods are the same as for recurrence.

In the non-LSTR group, proportion MA yielded a value of 0.95% (95% CI = 0.001–0.025, I^2 = 16.2%).

In the LSTR group, proportion MA yielded a value of 2% (95% CI = 0.005–0.042, I^2 = 17.1%).

No significance was found between both groups (P = 0.6).

3.8.3. Avascular necrosis

Only 1 case (0.18%) of necrosis of the metatarsal head has been reported by Trnka et al. [26] in the LSTR group.

4. Discussion

The main finding of this meta-analysis is that LSML is found to be the most important element to be transected in order to obtain an optimal lateral release in mild and moderate HV. This MA could also explain the contradictory results reported in the literature over the role of the LTSR in the surgical management of hallux valgus deformity. When all studies are included in the analysis, no significance was found between LSTR and non-LSTR groups. However, subgroup analysis related to the HVA outcome demonstrated a high level of significance in favor of those which included the release of the LSML to their lateral release. This finding is in line with the most relevant anatomical study to our meta-analysis, that of Schneider [20], which demonstrated that when different sequential releases are performed, transecting the LSML was the key element to a successful complete reduction of HV deformity. Whatever is the sequence of the release, the dissection of the LSML, including incision of the lateral capsule and the lateral collateral ligament, allowed correction of the HVA and IMA as well as sesamoid subluxation. A second anatomical study [21] reported a complete reduction of HV deformity in 90% of the cases when partial tenotomy of the conjoined tendon was associated to a systematic release of the LSML. Only in 3 cases (10%), a tenotomy of the entire tendon was needed to correct the deviation. A relevant clinical study retrospectively comparing patients treated with a proximal osteotomy, one group having an additional release of the lateral capsule and LSML and another group having a complete LSTR, showed no difference in post-operative HVA, IMA and AOAFS values [22].

More, Schneider [20] reported that the transection of the attachment of the AddH had virtually no corrective effect. In fact, the included randomized study of Resch et al. [8] showed no statistical difference in HVA correction between patients having a Chevron and those having the Chevron associated with AddH tenotomy. A complete tenotomy of the AddH was performed in all our included studies. However, only in those where a LSML was associated to the tenotomy that significant correction was observed. It is likely that the tenotomy of the AddH yield no benefit in mild and moderate forms of HV deformity, such as those encountered in our review. Our findings along with those of the above-cited cadaveric studies concur that a lateral release could be first limited to the transection of the LSML along with the lateral capsule; only if the correction is not fully reduced that AddH tenotomy could be released from its attachment. The clinical study of Augoyrad et al. [16] which investigated the HVA and IMA values after each step of a sequential lateral release are also in line with our results. These authors demonstrated that, besides medial capsulorraphy, transecting the LMSL yielded the major contribution to HV correction. They also showed that in severe HV deformities, transection of the AddH significantly added to HVA reduction. No substantial benefit was found in releasing the AddH of the hallux from the fibular sesamoid. Our results also showed that TML might not contribute to HVA correction. Schneider [20] reported no effect of TML transection on HVA. On the other hand, Lui et al. [23] reported that the transection of the TML would facilitate the release of the conjoint tendon when an endoscopic approach is conducted. Taking into consideration the results of this analysis, a decisional tree is suggested to assist clinicians in preparing a case-by-case LSTR (Fig. 3).

In relation to IMA, a moderate significant difference was found between studies where LSTR including a TML transection when compared to osteotomy alone, favoring the former group. Our findings are in line with those of Schneider [20] who reported a reduction of 1.4° in IMA when TML was transected first. However, we could not find a significant difference when LSML was involved in opposition to Schneider's findings [20]. That could be due to the different type of LSTR in those studies relevant to IMA; one study transected the TML [14] while the other did not [17]. We suggest releasing the TML only when the transection of the LSML and the AddH do not achieve a full reduction of HV deformity.

The findings of this MA also reveal that sesamoid reduction is significantly better when LSTR is performed. However, the involved transected structures inducing this reduction could not be identified. Three out of four studies stated a transection of the AddH, the lateral capsule and the TML [6,7,15] where the fourth study [17] reported transection of the LSML instead of the TML. Some authors reported that the first metatarsal, not the sesamoid complex, is displaced medially relative to the sesamoids after distal osteotomies [18], since the position of the sesamoids relative to the second metatarsal is fixed [24–26]. Choi et al. [27] using a Chevron with complete LSTR concluded that metatarsal bone realignment reduced the sesamoid, but its position, relative to the second metatarsal axis, was unchanged. They also reported that the sesamoid is reduced by the lateral translation of the first metatarsal but not by medial sesamoid migration. There is still a debate as to whether post-operative sesamoid position affects functional outcome and patients' satisfaction after hallux valgus surgery [9,28,29]. Our included studies reporting both sesamoid position and AOFAS values did not show correlation between these two variables. In addition, no significant differences were found between both groups in relation to the range of motion and the rate of complications. Our results do not support reported claims [5,30] that avascular osteonecrosis and joint stiffness are more prevalent when LSTR is performed.

This MA has several limitations. A major one is the limited number of included studies. However, the total pool of 425 patients including 549 operated feet is likely to be adequate for analysis. More, all were of comparative design and two with randomization. Though the study of Woo et al. [17] reported the outcome of Chevron associated to Akin osteotomy, the" correction" outcome of the HVA between both groups would not be affected. Chevron osteotomy could be executed in few different ways, particularly with regard to the length of the plantar cut. We believe that such technical variations are unlikely to impact our results. We also attempted to locate relevant cadaveric studies to compare with our results. To add, the non-significance found when looking at the difference in HVA values upon including all studies is thought to be of value in supporting the fact that only particular lateral structures have a major role for correction. The lack of a standard detailed technique of the LSTR procedure could be another important limitation. For instance, some transect the AddH from the base of the first phalanx [8] while other performs the transection just over its attachment on the fibular sesamoid [17]. Some authors transected the lateral capsule totally [14] while others performed perforations to the capsule with the application of forced varus stress to gain reduction manually [15,17]. The mean follow-up of our included studies is around 2 years and the results might have change after longer follow-up. All LSTR reported in the included studies were performed via an open dorsal approach of the first webspace. It is likely that the same results could be drawn in case of trans-articular approach but such claim needs direct evidence.

5. Conclusion

This meta-analysis demonstrates a beneficial effect of lateral soft tissue release when associated to a distal osteotomy in correcting HV deformity. Lateral release reduces significantly the hallux valgus angle only when the lateral sesamoid metatarsal ligament is transected. It also concludes that the transection of other single lateral structures such as the adductor hallucis and the trans-metatarsal ligament are likely to have less corrective effect. These findings conclude that a lateral release could be first limited to the transection of the lateral sesamoid metatarsal ligament along with the lateral capsule. Only if the correction is not fully reduced that adductor tenotomy could be released from its attachment. Additionally, the results support a possible beneficial effect in correcting the intermetatarsal angle when the trans-

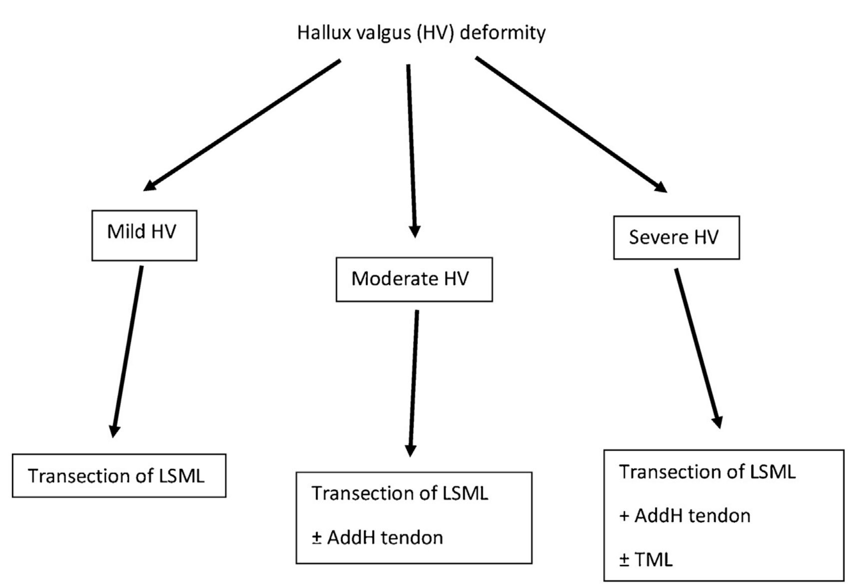

Fig. 3. Decisional tree for lateral soft tissue release.

metatarsal ligament is transected. The clinical implications of the results of this meta-analysis would be a beneficial effect of transecting the lateral sesamoid metatarsal ligament in all cases of hallux valgus deformity, a probable efficacy of an added adductor transection when the deformity is moderate and a possible efficacy of a third release via trans-metatarsal ligament transection in case of severe hallux valgus deformity.

Funding

None.

Conflict of interest

None.

References

[1] Durman D.C.. Metatarsus primus varus and hallux valgus. AMA Arch Surg 1957;74:128–35.
[2] Fraissler L, Konrads C, Hoberg M, Rudert M, Walcher M. Treatment of hallux valgus deformity. EFORT Open Rev 2016;1(8):295–302.
[3] Hardy RH, Clapham JC. Observations on hallux valgus based on a controlled series. J Bone Jt Surg Br 1951;33-B(3):376–91.
[4] Bai LB, Lee KB, Seo CY, Song EK, Yoon TR. Distal Chevron osteotomy with distal soft tissue procedure for moderate to severe hallux valgus deformity. Foot Ankle Int 2010;31:683–8.
[5] Granberry WM, Hickey CH. Hallux valgus correction with metatarsal osteotomy: effect of a lateral distal soft tissue procedure. Foot Ankle Int 1995;16:132–8.
[6] Grle M, Vrgoc G, Bohacek I, Hohnjec V, Martinac M, Brkic I, et al. Surgical treatment of moderate hallux valgus: a comparison of distal chevron metatarsal osteotomy with and without lateral soft-tissue release. Foot Ankle Spec 2017;10(6):524–30.
[7] Trnka HJ, Zembsch A, Kaider A, Salzer M, Ritschl P. Correction of high-grade sesamoid bone dislocation in hallux valgus using Austin's osteotomy with and without lateral soft tissue release. Z Orthop Ihre Grenzgeb 1997;135:150–6.
[8] Resch S, Stenström A, Reynisson K, Jonsson K. Chevron osteotomy for hallux valgus not improved by additional adductor tenotomy. A prospective, randomized study of 84 patients. Acta Orthop Scand 1994;65(5):541–4.
[9] Okuda R, Kinoshita M, Yasuda T, Jotoku T, Kitano N, Shima H. Postoperative incomplete reduction of the sesamoids as a risk factor for recurrence of hallux valgus. J Bone Jt Surg Br 2009;91(7):1637–45.
[10] Owens S, Thordarson DB. The adductor hallucis revisited. Foot Ankle Int 2001;22:186–91.
[11] Kuhn MA, Lippert 3rd FG, Phipps MJ, Williams C. Blood flow to the metatarsal head after chevron bunionectomy. Foot Ankle Int 2005;26(7):526–9.
[12] Okuda R, Kinoshita M, Morikawa J, Jotoku T, Abe M. Distal soft tissue procedure and proximal metatarsal osteotomy in hallux valgus. Clin Orthop Relat Res 2000;379(1):209–17.
[13] Veri JP, Pirani SP, Claridge R. Crescentic proximal metatarsal osteotomy for moderate to severe hallux valgus: a mean 12.2 year follow-up study. Foot Ankle Int 2001;22(10):817–22.
[14] Lee HJ, Chung JW, Chu IT, Kim YC. Comparison of distal Chevron osteotomy with and without lateral soft tissue release for the treatment of hallux valgus. Foot Ankle Clin 2010;31:291–5.
[15] Shi GG, Henning P, Marks RM. Correlation of postoperative position of the sesamoids after chevron osteotomy with outcome. Foot Ankle Int 2016;37(3):274–80.
[16] Augoyard R, Largey A, Munoz MA, Canovas F. Efficacy of first metatarsophalangeal joint lateral release in hallux valgus surgery. Orthop Traumatol Surg Res 2013;99(4):425–31.
[17] Woo K, Yu IS, Kim JH, Sung KS. Effect of lateral soft tissue release on sesamoid position in hallux valgus surgery. Foot Ankle Int 2015;36(12):1463–8.
[18] Lamo-Espinosa JM, Flórez B, Villas C, Pons-Villanueva J, Bondía JM, Aquerreta JD, et al. The relationship between the sesamoid complex and the first metatarsal after hallux valgus surgery without lateral soft-tissue release: a prospective study. J Foot Ankle Surg 2015;54(6):1111–5.
[19] Garrow AP, Papageorgiou A, Silman AJ, Thomas E, Jayson MI, Macfarlane GJ. The grading of hallux valgus: the Manchester Scale. J Am Podiatr Med Assoc 2001;91:74–8.
[20] Schneider W. Influence of different anatomical structures on distal soft tissue procedure in hallux valgus surgery. Foot Ankle Int 2012;33(11):991–6.
[21] Hromádka R, Barták V, Bek J, Popelka Jr. S, Bednářová J, Popelka S. Lateral release in hallux valgus deformity: from anatomic study to surgical tip. J Foot Ankle Surg 2013;52(3):298–302.
[22] Wagner E, Ortiz C, Figueroa F, Vela O, Wagner P, Gould JS. Role of a limited transarticular release in severe hallux valgus correction. Foot Ankle Int 2015;36(11):1322–9.
[23] Lui TH, Chan KB, Chan LK. Endoscopic distal soft-tissue release in the treatment of hallux valgus: a cadaveric study. Arthroscopy 2010;26(8):1111–6.
[24] Judge MS, LaPointe S, Yu GV, Shook JE, Taylor RP. The effect of hallux abducto valgus surgery on the sesamoid apparatus position. J Am Podiatr Med Assoc 1999;89(11–12):551–9.
[25] Ramdass R, Meyr AJ. The multiplanar effect offirst metatarsal osteotomy on sesamoid position. J Foot Ankle Surg 2010;49:63–7.
[26] Saragas NP, Becker PJ. Comparative radiographic analysis of parameters in feet with and without hallux valgus. Foot Ankle Int 1995;16:139–43.
[27] Choi YR, Lee SJ, Kim JH, Kim TH, Oh CH. Effect of metatarsal osteotomy and open lateral soft tissue procedure on sesamoid position: radiological assessment. J Orthop Surg Res 2018;1:11.
[28] Chen JY, Rikhraj K, Gatot C, Lee JY, Singh Rikhraj I. Tibial sesamoid position influence on functional outcome and satisfaction after hallux valgus surgery. Foot Ankle Int 2016;37(11):1178–82.
[29] Wilson JD, Baines J, Siddique MS, Fleck R. The effect of sesamoid position on outcome following scarf osteotomy for hallux abducto valgus. Foot Ankle Surg 2008;15(2):65–8.
[30] Peterson DA, Zilberfarb JL, Greene MA, Colgrove RC. Avascular necrosis of the first metatarsal head: incidence in distal osteotomy combined with lateral soft tissue release. Foot Ankle Int 1994;15:59–66.