Impact of forefoot width variation on clinical and functional outcomes following the Lapidus procedure

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Abstract

Purpose This study aimed to evaluate the effect of variations in bony and soft tissue foot widths on clinical and functional outcomes after hallux valgus correction with the Lapidus procedure.

Methods Forty-three feet in 35 patients with a mean follow-up of 18.5 months undergoing the LP were reviewed. Clinical and functional data were assessed with the VAS for pain, AOFAS Scale, LEFS and SF-12 health survey, which is divided into physical and mental health composite scales (PCS-12 and MCS-12). Radiographic analysis of forefoot width was based on bony and soft tissue limits. Intermetatarsal-angle and HV-angle were also assessed.

Results Bony width changed significantly from 95.5 mm to 84.2 mm (11.8%) and soft tissue width from 107.12 mm to 100.84 mm (5.86%) (p < 0.001). IMA and HVA improved significantly. Significant clinical and functional improvements were observed, except in MCS-12. In simple linear regression, correlation was found between variations of bony width with Δ-AOFAS and Δ-PCS-12, meaning that as the forefoot narrows, their values increase (p = 0.02 and p = 0.005, respectively). It was also related to Δ-IMA, meaning that the forefoot narrows as these parameters improve (p < 0.001 and p < 0.001). Soft tissue width was related to Δ-PCS-12 and Δ-AIM. In multiple linear regression, the strongest correlation was between bony width variation and Δ-IMA (p = 0.029, r² = 0.22).

Conclusion Forefoot narrowing was correlated with improved clinical and functional outcomes, as measured by AOFAS and PCS-12. In addition, correction of the radiographic parameters, mainly IMA, reflected on a significant decrease in the forefoot width.

Keywords Hallux valgus · Lapidus · Forefoot width
Introduction

The Lapidus procedure (LP) is a powerful technique that often provides significant corrections of hallux valgus (HV) deformities with reestablishment of the radiographic parameters [1, 2]. It is mainly indicated for pain relief and biomechanical and functional improvement, although patients are often concerned about cosmesis [3–5]. Correction of radiographic deformities is not the only factor that reflects on the clinical outcomes and patient satisfaction. Patients with less than perfect correction are often satisfied with the foot appearance after surgery and improvement in footwear problems [5–7]. Schneider and Knahr interviewed a series of patients who underwent HV correction and have found that decrease in pain and improved footwear use were the most important factors in the postoperative outcomes [5]. Saro et al. [8] reported that free choice of shoe wear had a significant positive effect in quality of life. One of the aspects that changes significantly with the LP are the forefoot width as demonstrated by other authors. However, it has not yet been reported whether foot narrowing after LP reflects on clinical and functional outcomes.

This study aimed to evaluate the effect of variations in bony and soft tissue foot widths (BSTW) as measured in the anteroposterior (AP) radiographs on clinical and functional outcomes after HV correction with the LP. Secondly, we tried to assess the relationship of the angular measurements of HV with changes in BSTW.

Materials and methods

This is a retrospective study that included 43 feet in 35 patients with a mean follow-up of 18.5 (range, 6–51) months who underwent the LP, from March 2015 to August 2021. Approval for this study was obtained from our Institutional Review Board (IRB). All procedures were performed by two fellowship-trained foot and ankle orthopedic surgeons from a single institution. Patient’s mean age was 47.8 (range, 18–73) years. Thirty (86%) patients were female and five (14%), male. Mean body mass index (BMI) was 24.9 (range, 19.13–33.2). Twenty-three procedures were performed on the left foot and 20 on the right foot (Table 1). Eight patients (23%) underwent HV correction on both feet, but in separate stages. Thirty feet (70%) underwent an ipsilateral Akin osteotomy. The modified Lapidus was performed in 6 feet (14%) and the original procedure in 37 (86%).

Patients who were 18 years or older at the time of surgery with a minimum postoperative follow-up of 6 months of HV correction with the LP were included in the study. The indication for the LP were moderate and severe HV deformities according to the Mann and Coughlin’s classification [9], associated with hypermobility of the first ray which was estimated preoperatively by manual stress examination and indicative signs on plain radiographs of the foot such as plantar gap between first metatarsal (M1) and medial cuneiform (MC) or subluxation of this joint, and cortial hypertrophy of the second metatarsal (M2). Depending on the presence of pre- and intraoperative radiographic signs of transverse instability, we performed the original or modified version of the LP. It was confirmed by visualization of the widening of the space between M2 and MC with or without opening of the intercuneiform joint in the anteroposterior view of preoperative radiographs or after intraoperative hook test. Patients with prior surgery for HV or bunionette and comorbidities that could interfere with bone healing such as smoking, diabetes or inflammatory joint diseases were excluded from this study. Patients with HV associated with a progressive collapsing foot deformity were also excluded.

Measurements

Bony and soft tissue widths measurements, as well as the standard HV radiographic parameters such as intermetatarsal angle (IMA) and HV angle (HVA) were assessed. Bony width was measured from the most medial extent of the cartilage surface of the M1 to the most lateral extent of the fifth metatarsal (M5) head. Soft tissue width was calculated considering the most medial and lateral shadow of the foot (Fig. 1). All measurements were performed by 2 independent fellowship-trained foot and ankle orthopedic surgeons. HV angles were measured according to the principles of the guideline described by the Ad Hoc Committee of the American Orthopaedic Foot and Ankle Society on Angular Measurements [10]. All measurements were calculated using the digital caliper of Vue Motion software (Carestream Health, Rochester, NY, USA).

Clinical and functional analysis were based on patient-reported questionnaires such as the visual analogue scale (VAS) for pain, the American Orthopaedic Foot and Ankle Society (AOFAS) Hallux

| Table 1 | Average intra-class correlation coefficients for bony and soft tissue foot widths |
|---------|--------------------------------------------------------------------------------|
| ICC     | Preoperative mean (95% CI) | Postoperative mean (95% CI) |
| Bony foot width | 0.95 (0.9–0.97) | 0.95 (0.91–0.97) |
| Soft tissue width | 0.95 (0.9–0.97) | 0.95 (0.9–0.97) |

ICC Intra-class correlation coefficients, CI Confidence interval
Metatarsophalangeal-Interphalangeal Scale, the Lower Extremity Functional Scale (LEFS) and the Short-form 12 (SF-12) health survey [11–14]. The SF-12 is a survey tool that comprises twelve items, which are divided into physical and mental health composite scales (PCS-12 and MCS-12, respectively). All scores were collected preoperatively and at the latest patient follow-up records.

Operative technique

The LP was performed through two separate approaches. First, a longitudinal-medial 3-cm incision, parallel to the ground and centered over the M1 head, was fashioned for the bunion exostectomy. Next, a longitudinal dorsomedial incision of 3 to 4-cm centered over the tarsometatarsal joint (TMTJ) was performed, medially to the extensor hallucis longus tendon. After skin dissection, TMTJ capsule was longitudinally incised and its plantar portion was released with an osteotome to facilitate M1 base manipulation allowing proper visualization of the entire joint. TMTJ surfaces were denuded of cartilage with a delicate oscillating saw blade, removing less underlying bone as possible to avoid excessive shortening of the first ray. In order to create a better healing surface between M1 and M2, we followed the following steps: (1) a small dorsolateral portion of the M1 base was resected with a saw blade; (2) the medial face of the M2 base was burred with an osteotome along the metatarsal longitudinal axis, removing cortical bone; (3) drilling of subchondral bone was performed in the TMTJ and medially in the M2 base with a 1.5 mm Kirschner Wire. A 2 mm Steinmann pin was perpendicularly inserted on the proximal portion of the M1, allowing supination and angular movements of the M1, correcting pronation, elevation and varus deformities. M1 was also translated laterally toward M2 for further correction to improve coverage of the sesamoid bones. Realignment of first ray was then checked on AP fluoroscopy view. For patients undergoing the original Lapidus, fixation consisted of two 3,5 mm cannulated compression partially threaded screw from the M1 to the M2 and from the M1 to the MC, complemented by a medial locked neutralization plate. Autogenous cancellous bone graft derived from the resected M1 medial prominence was inserted between M1 and M2 after arthrodesis fixation according to the coaptation of these bones. In the modified version, the space between M1 and M2 was preserved and no plate was used for TMTJ fusion. Fixation was performed with two 3, 5 mm cannulated compression partially threaded screw from the M1 to the MC in a crossed pattern. Verification of sagittal alignment of the M1 was performed clinically in the frontal view of the foot, with the M1 at the same level as the fifth metatarsal. At this point of surgery, the Akin procedure was indicated in the presence of an interphalangeal valgus deformity.

Postoperatively, patients remained non-weight bearing for 2 weeks for pain control and soft tissue healing without a splint or boot. At 2 weeks, stitches were removed and progressive weight bearing using a postoperative hard-sole sandal (HSS) was allowed. After 8 weeks from surgery, HSS was discontinued if radiographic signs of TMTJ fusion site were present in the anteroposterior and lateral radiographic views. At 4 months postoperatively, patients were allowed to resume all previous activities according to the rehabilitation process.

Statistical analysis

Pre and postoperative radiographic, clinical and functional variables were compared using paired Mann–Whitney test. Intraclass Correlation Coefficients (ICC) were calculated for BSTW. Simple linear regression was used to assess the correlation of Δ-BSTW with each clinical, functional and radiographic measurement. Multiple linear regression was also performed to evaluate which variable was most strongly associated with Δ-BSTW. All statistical analysis was performed using R Software (Version 4.0.2). P values of less than 0.05 were considered statistically significant.

Results

Pre and postoperative ICC for bony and soft tissue foot width measurements had high interobserver reliability (Table 1). All feet presented decrease in BSTW after surgery. Overall
bony width narrowed a mean of 11.8%, from 95.5 mm (range, 82.83–107.55) to 84.2 mm (range, 70–100.6) and overall soft tissue width decreased an average of 5.85%, from 107.12 mm (range, 89.25–118.65) to 100.84 mm (range, 85.02–113.68) (p < 0.001 and p < 0.001, respectively). IMA and HVA improved significantly. The mean IMA decreased significantly from 16.55 (range, 12.15–24.3) preoperatively to 9.55 (range, 3.8–17.8), postoperatively (p < 0.001). Mean preoperative HVA changed significantly from 36.83 (range, 20.65–52.47) to 13.19 (range, 1.72–30.68) in the postoperative evaluation (p < 0.001) (Table 2).

Significant clinical and functional improvements were observed in most questionnaires except in MCS-12, which is the SF-12 mental component (Table 3). The mean preoperative to postoperative VAS decreased from 8.32 (range, 4–10) to 1.51 (range, 0–6) (p < 0.001). The mean preoperative AOFAS increased from 40.67 (range, 25–60) to 85.20 (range, 58–100) postoperatively (p < 0.001). The mean PCS-12 increased from 41.14 (range, 21.6–57.46) preoperatively to 53.14 (range, 41.88–59.92) postoperatively (p < 0.001). The mean preoperative to postoperative MCS-12 did not change. Its value varied from 49.82 (range, 23.77–64.95) to 51.64 (range, 25.58–61.22), respectively (p = 0.468). The mean LEFS increased from 58.30 (range, 21–84) preoperatively to 77.07 (64–84) postoperatively (p < 0.001).

In simple linear regression, a correlation was found between Δ-BSTW and radiographic, clinical and functional outcomes. Bony width variations were related Δ-AOFAS and Δ-PCS-12, meaning that as the forefoot narrows, their values increase (p = 0.02 and p = 0.005). It was also related to Δ-IMA, meaning that the forefoot narrows as these parameters improve (p < 0.001). Soft tissue width variations were similarly related to Δ-PCS-12 and Δ-AIM (p = 0.049 and p = 0.005). In multiple linear regression, the strongest correlation observed was between bony width variation and Δ-IMA (P = 0.029, r² = 0.22).

**Discussion**

The present study found that foot narrowing positively correlates with clinical and functional outcomes using the BSTW measures. It also demonstrated that realignment of the M1 varus (Δ-IMA) was strongly correlated to the BSTW. This study brings to light the potential importance of final foot width on patient outcomes. Possibly, the narrower the foot is at the end of the procedure, the better clinical results will be perceived by the patient. Furthermore, this study suggests that adequate correction of IMA is the most effective way of achieving a narrow foot, and consequently better clinical scores.

We conducted these evaluations as there is still scarce data in this issue, especially regarding to LP. Most studies addressing forefoot width were mainly based on radiographic parameters variations after corrections with osteotomies [15–17]. Jung et al. [15] assessed 117 feet and

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**Table 2** Pre- and postoperative radiographic measures in the anteroposterior weightbearing radiographic foot view

|                | Bony width (95% CI) | Soft tissue width (95% CI) | HVA (95% CI) | IMA (95% CI) |
|----------------|---------------------|-----------------------------|--------------|--------------|
| Preoperative   | 95.5 (20.06 to 22.08) | 107.12 (−5.64 to −0.89)    | 34.7 (33 to 36.40) | 16.85 (16.18 to 17.53) |
| Postoperative  | 84.2 (17.18 to 19.99) | 100.84 (−6.69 to −2.76)    | 13.52 (11.67 to 15.36) | 9.7 (8.88 to 10.52) |
| p              | <0.001*             | <0.001*                     | <0.001*       | <0.001*       |

Mann–Whitney test

CI Confidential interval, HVA Hallux valgus angle, IMA Intermetatarsal angle

*Significance at p < 0.05

**Table 3** Pre- and postoperative clinical and functional outcomes

|                | VAS (95% CI) | AOFAS (95% CI) | LEFS (95% CI) | PCS-12 (95% CI) | MCS-12 (95% CI) |
|----------------|-------------|----------------|--------------|----------------|-----------------|
| Preoperative   | 8.19 (7.62–8.76) | 40.41 (36.89–43.94) | 54.22 (48.87–59.56) | 40.42 (37.22–43.61) | 50.11 (46.39–53.83) |
| Postoperative  | 1.41 (0.8–2.02) | 85.25 (81.29–89.2) | 73.52 (71.34–75.7) | 53.27 (51.71–54.83) | 51.50 (48.25–54.74) |
| p              | <0.001*     | <0.001*        | <0.001*       | <0.001*        | 0.954           |

Mann–Whitney test and Student t test

CI Confidential interval, VAS Visual analogue scale for pain, AOFAS American orthopedic foot and ankle society hallux metatarsophalangeal-interphalangeal scale, LEFS Lower extremity functional scale, PCS-12 SF-12 physical composite scale, MCS-12 SF-12 mental composite scale

*Significance at p < 0.05
found that forefoot width decreased by 16% after proximal Chevron associated with modified McBride release, Akin osteotomy and medial eminence resection. Panchbhavi et al. [16] performed the distal Chevron with the Akin osteotomy in 52 patients and observed that forefoot narrowed by an average of 8.7 mm. Tenenbaum et al. studied a group of 71 cases that underwent midshaft osteotomy as Scarf. Overall bony width was reduced by 5% and soft tissue by 2%. These studies have conflicting results, as they evaluated different osteotomies sites and used different landmarks on the first ray to calculate the medial limits.

Our cohort of patients showed similar amount of BSTW variations compared to other studies that corrected HV deformities with the LP. Bony width narrowed significantly by 11.8% and soft tissue width by 5.85%. Conti et al. reported significant decreases in bony width of 9.1% and soft tissue width of 6.3% after performing a modified Lapidus in a group of 31 feet assessed by weightbearing radiograph and computed tomography (WBCT) scans. They used the most medial extent of the M1 head and the most lateral M5 head as references for bony width and the most medial and lateral extents of the foot shadow for soft tissue width. However, all their patients had associated procedures as the modified McBride release and Akin osteotomy [18]. Vaida et al. evaluated 148 feet and have found similar decreases in both bony and soft tissue widths of 10.8% and 6.8%, respectively. In contrast, not all patients in their cohort underwent additional procedures and they have not resected the medial eminence [19]. Differently from the aforementioned studies, we have found that forefoot narrowing not only impacts in cosmesis, but it also plays a role on clinical and functional outcomes after surgery. In addition, all our patients have had medial eminence resection and 70% had associated Akin osteotomy. Concerning radiographic methods of analysis, our study is similar to Vaida’s study in that both have used only conventional AP radiographic views while Conti took WBCT scans as well. In our point of view, our results are reproducible and comparable as shown by similar bony and soft tissue amount of decrease in forefoot width. As in Conti’s study, we have found a moderate correlation of only the Δ-IMA with bony width variation [18].

The current study brings a new insight into forefoot narrowing after the LP, showing it was directly related to clinical and functional improvements. Other notable strength that can be recognized was that IMA was the most significant radiographic variable that influenced bony width variations. Since all procedures were performed by the same two foot and ankle surgeons, there were few variabilities regarding operative technique and postoperative protocol.

Our study has some limitations, mainly its retrospective design and small sample size. However, all data were based on a prospectively collected registry from March 2015 to August 2021. In addition, although a small sample size was analyzed without previous power analysis, it was sufficient to demonstrate a strong correlation of Δ-BSTW with clinical and functional improvements in Δ-AOFAS and Δ-PCS-12 questionnaires. Other limitations were that our patients underwent different variations of the LP and the Akin procedure was not performed in all of them, which can slightly influence width measures. Medial eminence resection usually varies from patient to patient, which may also have an impact. However, we controlled the resected amount by starting the osteotomy at the most medial limit of the M1 head cartilage cover. In an attempt to decrease discrepancy between our radiographic measurements, we established the medial limit of the cartilage surface as the medial reference point, since it wouldn’t be resected in the bunionectomy. Finally, a considerable difference between bony and soft tissue changes was observed. The decrease in forefoot soft tissue width may be underestimated due to postoperative edema.

In conclusion, we were able to show that narrowing of the forefoot after the LP positively correlates with clinical and functional outcomes, as measured by AOFAS and PCS-12. Furthermore, it demonstrated that radiographic parameters of the HV, mainly IMA, reflects on the forefoot width, showing the importance of adequately correcting this radiographic parameter during the LP. Further prospective and comparative studies with larger populations are required to evaluate the effects of forefoot width changes on clinical and functional outcomes.

Author contributions DRCN and FAD performed the operations. DRCN, FAD and BRM collected data. Material preparation was performed by all authors. First draft of the manuscript was written by DRCN and GHS, and all authors commented for adequate changes of its final version. All authors read and approved the final manuscript.

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Declarations

Conflicts of interest DRCN, FAD, PAP, AAMM: none. MPP: education consultant for Arthrex. GHS: education consultant for Stryker.

Ethical approval This study was performed in accordance with the Helsinki Declaration of 1964, and ethical approval was obtained from Ethics Committee of Hospital do Servidor Municipal de São Paulo (HSPM) with CAAE number 53836221.2.0000.5442.

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