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Original Article

Three-dimensional assessment of hallux valgus correction using the Lapicotton technique

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Abstract

Objective: The objective of the study was to assess the efficacy of the LapiCotton procedure on patients with hallux valgus (HV) combined with medial longitudinal arch collapse.

Methods: Preoperative and postoperative weight-bearing computed tomography (WBCT) scans were obtained from patients with HV submitted to the LapiCotton procedure. Semi-automatic measurements were applied to 22 WBCT images across 11 patients enrolled in the study using a software package (Bonelogic, Disior™, Helsinki, Finland). Significance level was set at 0.05.

Results: The hallux valgus angle (HVA) was significantly larger (p=0.026) in the preoperative group (Mdn = 27.52) than in the postoperative group (Mdn = 20). In addition, the Meary sagittal measurement was found to be significantly increased (p=0.033) in the preoperative group (Mdn = -14.28) when compared to the postoperative group (Mdn = -11.15). It was also observed that the intermetatarsal angle was significantly larger (p=0.003) in the preoperative group (Mdn = 15.68) compared to the postoperative group (Mdn = 11.26).

Conclusion: The LapiCotton procedure effectively corrected radiographic parameters in patients with HV combined with the medial longitudinal arch collapse.

Level of Evidence III; Therapeutic Studies; Comparative Retrospective Study.

Keywords: Flatfoot; Hallux valgus; Orthopedic procedures; Weight-bearing; Tomography, x-ray computed.

Introduction

Hallux valgus (HV) is one of the most common foot and ankle deformities involving the first ray. The hallux valgus angle (HVA), intermetatarsal angle (IMA), proximal phalangeal articular angle, distal metatarsal articular angle, interphalangeal angle (IPA), and sesamoid rotation (SR) are important metrics that are used in diagnosis, surgical planning, and postoperative analysis[1,2]. Hallux valgus is best evaluated using weight-bearing computed tomography (WBCT), as this three-dimensional (3D) imaging modality is not influenced by foot projection or orientation and allows for visualization of multiplanar bone anatomy in an upright position[3]. In addition, WBCT inherently provides images in 3D to offer a complete way to assess patients with HV, allowing for accurate measurements of HVA, IMA, IPA, and SR[4].

Study performed at the UIOWA Orthopedic Functional Imaging Research Laboratory (OFIRL). University of Iowa, Carver College of Medicine, Department of Orthopedics and Rehabilitation, Iowa City, IA, USA

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It is a well-established concept in the literature that the first ray and the entire medial column play a crucial role in preserving the tripod of the foot[5]. Furthermore, changes to the biochemical and structural properties of the first ray, along with the medial longitudinal arch collapse, have been associated with HV. Thus, restoring the first ray plays an important role when restoring the mechanical function of the foot tripod in the setting of HV combined with medial longitudinal arch collapse.

Treating HV using the modified Lapidus procedure, where the first tarsometatarsal (TMT) joint is fused, can pose a challenge in maintaining the length and avoiding dorsal inclination of the distal part of the first ray. This can hinder the mechanical advantage provided by the first ray in correcting medial longitudinal arch collapse for patients with HV[6]. Therefore, the Cotton osteotomy attempts to fix the plantar inclination of the distal part of the first ray to rebuild the triangle of the foot support through a dorsal opening wedge of the medial cuneiform.

The LapiCotton is a surgical technique, recently described by de Cesar Netto et al.[6], that combines the mechanical advantages of a Cotton osteotomy and a modified Lapidus procedure. It is used to treat the collapse of the medial column through the fusion of the first TMT joint using a dorsal wedge distraction allograft. This procedure maintains the length of the first ray and restores the medial longitudinal arch by the plantar inclination of the distal part of the first ray in the foot tripod. Simultaneously, the procedure allows for conventional corrections of rotational and transverse plane malalignment[6].

In light of this knowledge, the aim of our study is to assess the efficacy of the LapiCotton procedure on patients with HV combined with medial longitudinal arch collapse. Our hypothesis is that the LapiCotton procedure will produce a reliable correction of HV, and medial longitudinal arch collapse, based on semi-automatic WBCT measurements of HVA, IMA, Meary angle, and SR.

Methods

Design

This research study complied with the Health Insurance Portability and Accountability Act (HIPAA) and was approved by the University of Iowa's IRB (ID# 201904825). It also complied with the Declaration of Helsinki. Weight-bearing computed tomography scans were obtained from patients with HV before and after the LapiCotton procedure, with the postoperative scans being scheduled approximately three months after the surgery date.

Patients

Patients were enrolled from February 2020 to August 2021 for the preoperative WBCT scans. The final postoperative WBCT scan was obtained in January 2022. Preoperative and postoperative scans were obtained for the foot and ankle unilaterally or bilaterally, but LapiCotton procedures were performed only unilaterally for patients in this study. Semi-automatic measurements were applied to 22 WBCT images across 11 patients enrolled in the study (unilaterally applied per WBCT scan, with two scans per patient) using the Disior® Bonelogic® Foot and Ankle Software (version 2.1; Helsinki, Finland). The patients with HV (mean age 51 years, median 51, standard deviation 10.82, range 27-63) were 64% female and 36% male with a mean Body Mass Index (BMI) of 28.78 (median 29.36, standard deviation 5.06, range 21.79-39.75). Among the patients, 9% had diabetes, 9% smoked, and 9% had rheumatoid arthritis.

Imaging acquisitions

Weight-bearing computed tomography scans were performed with a cone-beam CT extremity scanner (pedCAT® Model, CurveBeam®, Warrington, USA). Patients entered the device and were positioned in a bipedal standing position. A radiography emitter and a flat-panel sensor on the opposite side rotated horizontally around the feet. Images were acquired at 120kVp and 5mA with a maximum exposure of 10s. The volume was reconstructed with a 0.37 mm isotopic voxel[7].

WBCT semi-automatic 3D measurements

The semi-automatic 3D measurements were performed by a fellowship-trained orthopedic foot and ankle surgeon using the Disior® Bonelogic® Ortho Foot and Ankle Software (version 2.1; Helsinki, Finland) for the following measurements (Figure 1): Meary angle (sagittal), HVA, IMA, and SR[3,8].

Statistical analysis

Standard descriptive statistics (mean, median, interquartile range (IQR), and standard deviation) were calculated for the following measurements: Meary angle (sagittal), HVA, IMA, and SR. Intraclass correlation coefficients were calculated for continuous data. Normality of variable distributions was evaluated using the Shapiro-Wilk test. A paired t-test was used to evaluate the difference in means between preoperative and postoperative values for each measurement. Significance level was set at 0.05.

Results

This study found that the HVA was significantly larger ($p=0.026$) in the preoperative group (Mdn = 27.52) than in the postoperative group (Mdn = 20). In addition, the Meary sagittal measurement (MSM) was found to be significantly different between groups ($p=0.033$), with a larger value seen in the preoperative group (Mdn = -14.28) compared to the postoperative group (Mdn = -11.15). It was also observed that the IMA was significantly larger ($p=0.003$) in the preoperative group (Mdn = 15.68) compared to the postoperative group (Mdn = 11.26). These findings are depicted in the associated figures (Figures 2, 3, and 4).

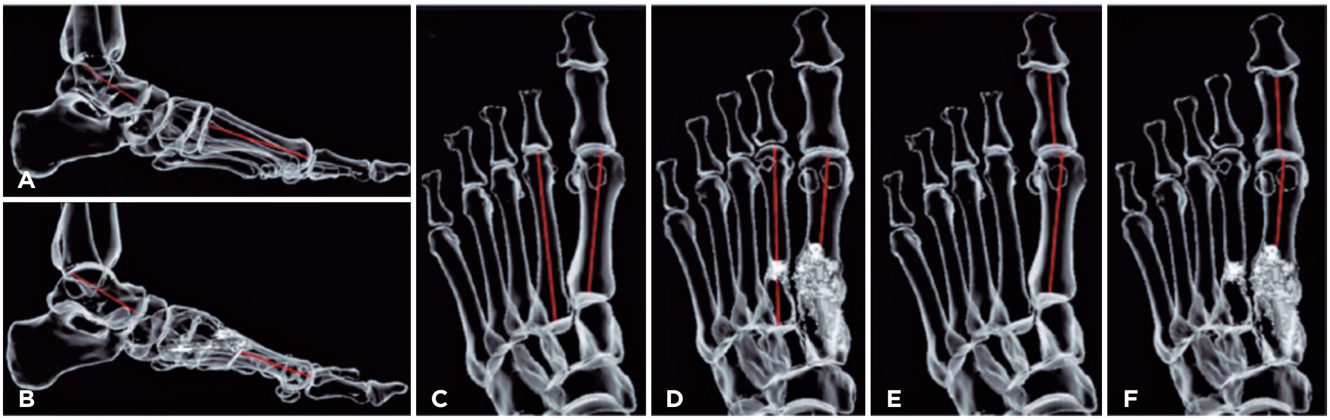

Figure 1. Three-dimensional semi-automatic WBCT measurements using the Disior Bonelogic Foot and Ankle Software (A) Meary angle, (C) Intermetatarsal angle, and (E) Hallux valgus angle, preoperative. (B) Meary angle, (D) Intermetatarsal angle, and (F) Hallux valgus angle, postoperative.

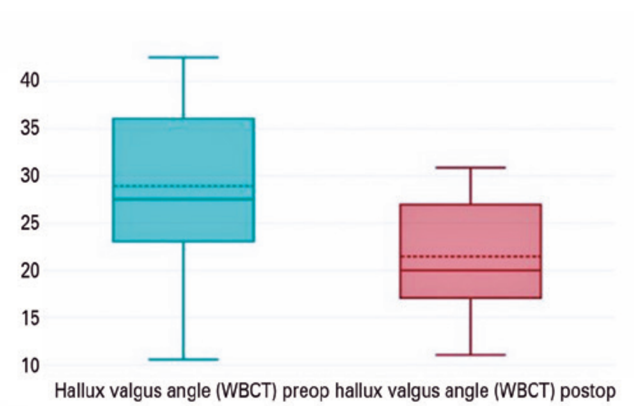

Figure 2. The Hallux valgus angle (WBCT) comparison between the preoperative and postoperative groups.

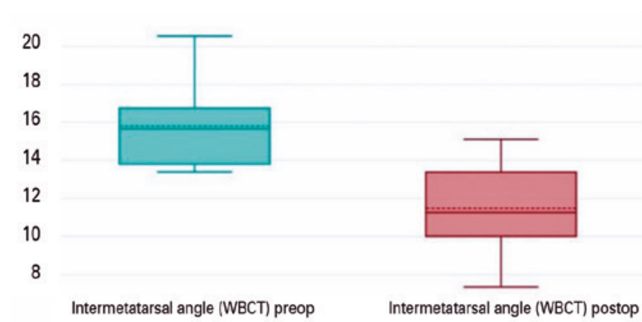

Figure 4. The Intermetatarsal angle (WBCT) comparison between the preoperative and postoperative groups.

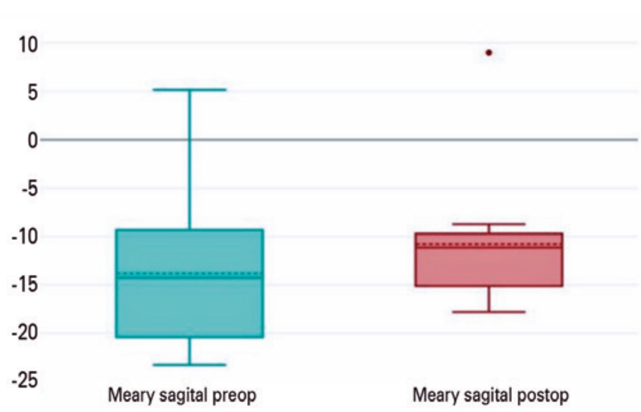

Figure 3. The Meary sagittal comparison between the preoperative and postoperative groups.

The SR was found to be higher in the preoperative group (Mdn = -17.71) than in the postoperative group (Mdn = -24.98); however, these values were not significantly different from one another (p=0.203). These findings supported a failure to reject the null hypothesis (Figure 5).

Discussion

This study focused on understanding the anatomical changes before and after surgery in patients with HV treated with the LapiCotton procedure. Weight-bearing computed tomography was utilized in this study because it is considered the best technique for quantification when measuring the horizontal and vertical alignment of HV[9-11]. Semi-automatic WBCT measurements of patients with HV, combined with medial longitudinal arch collapse, were taken before and after undergoing the LapiCotton procedure.

The LapiCotton technique was developed in an attempt to maintain the length of the first ray and, therefore, the integrity of the 3D foot tripod. In a recent prospective cohort study by de Cesar Netto et al.[6], the LapiCotton technique was performed to treat medial longitudinal arch collapse in 22 patients with either progressive collapsing foot deformity (PCFD), midfoot arthritis, or HV deformity. This study showed promising results, as the authors observed a low complication rate (9% minor, 4.5% major) and a high healing rate three months after surgery (91%). Furthermore, only two patients were observed to have non-union, one clinically stable and the other clinically unstable, which required reoperation[6]. These early results of the LapiCotton procedure show that this technique is relatively safe and effective for treating medial longitudinal arch collapse. These results also suggest that the LapiCotton procedure should be considered for patients with deformities that include medial longitudinal arch collapse. Therefore, we analyzed patients with HV deformity and medial longitudinal arch collapse to assess the effectiveness of the LapiCotton procedure in this patient population. Our hypothesis is that the LapiCotton procedure will produce a reliable correction of HV deformity combined with medial longitudinal arch collapse based on semi-automatic WBCT measurements.

To measure the effectiveness of the LapiCotton procedure in patients with HV and medial longitudinal arch collapse, we assessed four WBCT measurements that help define corrected HV; the HVA, MSM, IMA, and SR.

Hallux valgus angle

There was a statistically significant difference between the pre- and postoperative median HVA values (p=0.026), with a median preoperative HVA of 20° and median postoperative HVA of 27.52°. Hallux valgus angle is a well-accepted measure of the severity of HV deformity that is widely used in clinical practice. A measurement of less than 15° is considered normal. A classification of mild HV is a measurement of 16-25°, and moderate HV is 26-35°[12]. The LapiCotton procedure has shown promising results for patients with HV and has been shown to significantly reduce the severity of disease progression in this population.

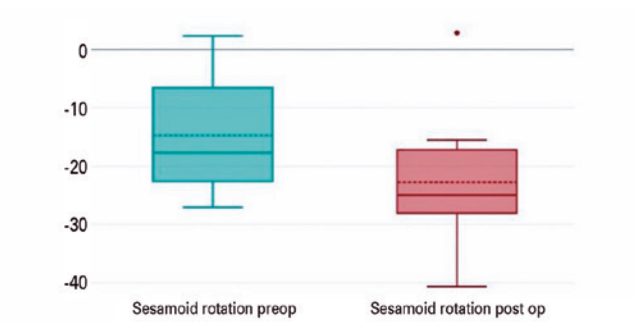

Figure 5. The sesamoid rotation comparison between the preoperative and postoperative groups demonstrating no statistical significance.

Meary sagittal measurement

There was also a statistically significant difference between the pre-and postoperative MSM (p=0.033), with a preoperative of -14.28 and postoperative of -11.15. This measurement is also used to measure the severity of HV disease progression. A value of less than 15º is considered mild deformity[13]. While both pre- and postoperative measurements were classified as mild deformities, the procedure could significantly decrease this angle to lessen the degree of the longitudinal axis of the talus and the first metatarsal.

Intermetatarsal angle

There was a statistically significant difference between the pre- and postoperative IMA (p=0.003), with a preoperative of 15.68° and postoperative of 11.26°. In literature, a normal IMA is less than 10°[12]. While the LapiCotton procedure has not fully corrected the IMA to normal physiological values, it has been shown to significantly decrease the IMA and lessen the severity of the deformity.

Sesamoid rotation

There was no statistically significant difference between the pre- and postoperative SR (p=0.203). However, the postoperative SR was higher in the preoperative group (-17.71) versus the post-operational group (-24.98). Although the LapiCotton procedure has been shown to produce no difference in this measurement postoperatively, Kim and Young have shown that the sesamoid subluxation may or may not be present in HV deformity, and this subluxation depends on different foot physiological scenarios[14].

When looking at these WBCT measurements, it is evident that the LapiCotton procedure successfully corrected HV deformity in patients with medial longitudinal arch collapse. The two most important imaging measurements to determine the severity of HV deformity are HVA and IMA[15]. The procedure produced significantly different measurements for both angles postoperatively, providing evidence that this procedure can successfully correct medial longitudinal arch collapse in patients with HV and radiographically reduce the severity of the deformity.

Limitations

This study has several limitations. First, this study used a small sample. It also did not include a control group or comparison with another surgical intervention. However, due to the novel treatment technique and goal to utilize semi-automatic measurements, we deemed it important to report changes in measurements after this surgical intervention. Additionally, no patient-reported outcomes (PROs) were utilized in this study. This information would be important for assessing changes in responses after the procedure and identifying any potential clinical correlations between measurements and PROs.

Conclusion

In conclusion, our hypothesis was confirmed. The LapiCotton procedure effectively corrected radiographic parameters in patients with HV combined with the medial longitudinal arch collapse. Reliable correction of HV, along with correction of medial longitudinal arch collapse, were quantified based on semi-automated WBCT measurements of HVA, IMA, and Meary angle. Future studies with a larger number of cases will help to strengthen the findings and evaluate the effectiveness of the LapiCotton procedure.

Authors' contributions: Each author contributed individually and significantly to the development of this article: VM *(https://orcid.org/0000-0002-8612-5941) Conceived and planned the activities that led to the study, interpreted the results of the study, participated in the review process and approved the final version; RJ *(https://orcid.org/0000-0003-3448-1300), and HS *(https://orcid.org/0000-0003-2664-0762), and GT *(https://orcid.org/0000-0002-0018-6410), and ES *(https://orcid.org/0000-0002-6922-5238) AF *(https://orcid.org/0000-0002-3905-9662), and *(https://orcid.org/0000-0002-3731-8448), and KCK *(https://orcid.org/0000-0003-1082-6490) Data collection and interpreted the results of the study; KAMC *(https://orcid.org/0000-0003-1082-6490) Interpreted the results of the study, participated in the review process and approved the final version; NSBM *(https://orcid.org/0000-0003-1067-727X), and CCN *(https://orcid.org/0000-0001-6037-0685), and KD *(https://orcid.org/0000-0002-8061-4453) Interpreted the results of the study and approved the final version. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID).

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