

Sesamoid complex angle correction after arthrodesis of the first cuneometatarsal joint in the treatment of hallux valgus

Correção angular do complexo sesamoide após artrodese da primeira articulação cuneometatarsal no tratamento do hálux valgo

Rafaela Affonso de Macedo¹, Helencar Ignácio¹, Márcio Gomes Figueiredo¹, Milena Bolini Cunha¹

1. Hospital de Base de São José do Rio Preto, São José do Rio Preto, SP, Brazil.

ABSTRACT

Objective: To evaluate the degree of sesamoid complex correction in patients with moderate and severe hallux valgus undergoing cuneometatarsal arthrodesis by comparing general pre- and postoperative values and also post-reduction outcomes between moderate and severe cases.

Methods: The radiographs of 24 patients (83.3% females and 16.7% males) who underwent arthrodesis of the first cuneometatarsal joint were retrospectively analysed. The patients' mean age was 52.58 years. The metatarsophalangeal, intermetatarsal and sesamoid dislocation angles were measured on the preoperative and immediate postoperative radiographs, with the former measured in the standing position and the latter measured intraoperatively, all in the anteroposterior incidence. The first metatarsal lateralization necessary to centralize the sesamoids was measured in degrees. We refer to this angle as the "angle to be corrected".

Results: We achieved sesamoid dislocation correction, reducing the indicated angles in relation to their preoperative values. Both moderate and severe cases showed statistically significant differences in angular correction after surgery, with $p=0.018$ and $p<0.001$, respectively. Comparing the moderate and severe cases, a statistically significant difference was observed preoperatively, with $p=0.007$; however, the results were not statistically significant postoperatively ($p=0.227$).

Conclusion: We achieved effective correction of the ABC in terms of both the total patient sample and the isolated analysis of the moderate and severe groups. Preoperatively, the moderate cases had smaller angles than the severe cases, but both groups exhibited reductions in these angles in the postoperative period and had similar outcomes.

Level of Evidence IV; Prognostic Studies; Case Series.

Keywords: Hallux valgus; Tarsal joints; Arthrodesis; Osteotomy/methods.

RESUMO

Objetivo: Avaliar o grau de correção do complexo sesamoideo dos hálux valgus moderados e graves submetidos à artrodese cuneometatarsal, comparando os valores pré e pós-operatórios de maneira geral e, também, a pós-redução entre os graus moderados e graves.

Métodos: Foram analisadas, retrospectivamente, radiografias de 24 pacientes submetidos à artrodese da primeira articulação cuneometatarsal, com média de idade de 52,58 anos, sendo 83,3% mulheres e 16,7% homens. A mensuração dos ângulos metatarsofalangiano, intermetatarsal e a luxação dos sesamoides foi feita em radiografias pré e pós-operatórias imediatas, sendo as primeiras ortostáticas, enquanto as últimas, intraoperatórias, ambas na incidência anteroposterior. Quantificou-se, em graus, a lateralização necessária do primeiro metatarso para se obter a centralização dos sesamoides, ângulo este que denominamos "ângulo a ser corrigido" (AAC).

Resultados: Obtivemos correção da luxação dos sesamoides, com redução dos valores angulares em relação ao pré-operatório. Tanto casos moderados como graves mostraram diferença estatisticamente significante para correção angular após o tratamento cirúrgico, com $p=0,018$

Work performed at Hospital de Base de São José do Rio Preto, SP, Brazil.

Correspondence: Rafaela Affonso de Macedo. Av. Brigadeiro Faria Lima, 5544, Vila São José, CEP:15090-000, São José do Rio Preto, SP, Brazil
E-mail: rafaela_am@hotmail.com

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e $p < 0,001$, respectivamente. Quando comparados entre si, casos moderados e graves apresentaram, também, diferença estatisticamente significativa, com $p = 0,007$ no pré-operatório, enquanto no pós-operatório os resultados foram estatisticamente não significantes ($p = 0,227$).

Conclusão: Obtivemos correção efetiva do AAC, tanto na amostra total de pacientes, como na análise isolada dos grupos moderado e grave. No pré-operatório, os casos moderados apresentaram graus menores do que os graves, porém ambos tiveram redução dos valores angulares de forma que, no pós-operatório, apresentaram valores semelhantes.

Nível de Evidência IV; Estudos Prognósticos; Série de Casos.

Descritores: Hallux valgus; Articulações tarsianas; Artrodesse; Osteotomia/métodos.

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INTRODUCTION

Among the various angular values that can be achieved with proper treatment of hallux valgus, the metatarsophalangeal hallux valgus angle and the intermetatarsal angle seem to have a strong correlation with clinical appearance and variable thresholds for determining severity^(1,2). Sesamoid subluxation on the first metatarsal head is common and is an important component of disease progression and potential recurrence of the deformity after surgical correction.^(3,4)

Some studies⁽³⁻⁶⁾ discuss the location of the sesamoid in relation to the forefoot as well as its relation to the metatarsal head. Geng et al.⁽³⁾ propose that subluxation is a result of medial displacement of the metatarsal head, with the sesamoid complex remaining in its original position.

Painful deformities that do not respond sufficiently to clinical treatment are eligible for surgical correction⁽¹⁾. Different procedures have been described to treat the various degrees of hallux valgus deformity^(7,8), and arthrodesis of the first tarsal-metatarsal joint, described in 1934 by Lapidus⁽⁹⁾, is well established and has been widely accepted for decades⁽¹⁰⁾. Although the procedure was originally indicated for correction of severe cases of adolescent metatarsus primus varus, the indications have evolved over the years. Currently, arthrodesis of the first tarsal-metatarsal joint is widely accepted for the treatment of moderate and severe adult hallux valgus with large displacement of the tibial sesamoid and also for cases of recurrence in which other techniques have failed⁽¹⁰⁻¹²⁾.

Some modifications have been developed to increase the stability of the technique and permit earlier weight-bearing, including fixation of the arthrodesis with a plate and screws, which produces greater stability from a mechanical point of view and may cause less pain, edema and/or other postoperative symptoms⁽¹⁰⁾. However, the procedure costs more than other proximal osteotomies^(7,13) and is

not without other complications, such as painful in the place of synthesis material and the need to remove the material^(11,13).

Another modification is the use of an additional bone fixation point, which can involve a Kirschner wire positioned transversely across the first and second metatarsal diaphyses^(10,11), complementing traditional interfragmentary fixation with compression screws. The purpose of the Kirschner wire is to minimize the lever arm effect on the first metatarsal, neutralizing the torque at the fusion focus and facilitating earlier weight-bearing on the foot⁽¹⁰⁾.

This study aims to evaluate the degree of angular correction in the immediate postoperative period in patients with moderate and severe hallux valgus undergoing surgical treatment using the modified Lapidus-type cuneometatarsal arthrodesis technique by comparing both pre- and postoperative outcomes in general and post-reduction outcomes between moderate and severe cases.

METHODS

This study was approved by the Ethics Committee with registration on the Brazil Platform under CAAE number: 83331618.8.0000.5415.

This was a descriptive, analytical, retrospective and quantitative study with radiographic evaluation of the feet of 24 patients undergoing arthrodesis of the first cuneometatarsal joint using the modified Lapidus technique between March 2014 and December 2017.

The mean patient age at surgery was 52.58 years (ranging from 15 to 76). Twenty patients (83.3%) were female, and 4 (16.7%) were male. Each patient had surgery on only one foot, including 8 left foot procedures and 16 right foot procedures. In all, 7 patients had moderate deformities and 17 had severe deformities.

Radiographs were accessed electronically by means of digital images according to Copyright© 2014 Agfa

HealthCare NV, Septestraat 27, B-2640, Mortsels, Belgium, and angular measurements were performed using the programme's digital resources. Preoperative radiographs with load and immediate postoperative radiographs with the knee flexed in the anteroposterior incidence were used. One examiner performed all the measurements in all cases only once.

We measured the metatarsophalangeal angle or that of the hallux valgus (HVA), the angle between the first and second metatarsals (IMA) and the position of the sesamoids (sesamoid dislocation) using criteria established by the American Orthopaedic Foot & Ankle Society,^(14,15) in which the first and second metatarsal reference points were positioned one centimetre from the proximal and distal articular surfaces at the centre of the diaphysis, respectively, and the reference point for the proximal phalanx was located 0.5 cm from the proximal and distal articular surfaces, as shown in figure 1.

Sesamoid dislocation was evaluated as the tibial sesamoid's position in relation to the mechanical axis of the first metatarsal, which was divided into 4 grades according to Smith's classification^(14,16).

The above angles were measured and sesamoid dislocation was quantified in the preoperative radiographs to classify the severity of the deformities using the Coughlin classification⁽⁵⁾ of light, moderate and severe.

To evaluate sesamoid dislocation correction, the first metatarsal lateralization required to achieve sesamoid centralization was measured in degrees to determine "the angle to be corrected" or the angular correction necessary to reposition the metatarsal head on the sesamoid complex⁽¹⁾.

This angle is measured between a line representing the mechanical axis of the first metatarsal and a line drawn from the base of the first metatarsal (with the exit point on its axis) passing distally through the centre of sesamoid complex, i.e., through the midpoint of the distance between the tibial and lateral sesamoids, as shown in figure 2.

The surgical procedure was performed dorsally, with a longitudinal incision medial to the extensor hallucis longus, centred on the lateral cortex of the first metatarsal, and extending proximally to the medial wedge. Preparation of the joint included removal of a base wedge lateral to the first metatarsal, curettage to remove the medial cuneiform



Figure 1. Location of the reference points for the first and second metatarsals and the proximal phalanx of the hallux.
Source: Author's personal archive.



Figure 2. Anteroposterior radiograph of a patient with hallux valgus. The drawn lines represent the angle to be corrected - ABC.
Source: Author's personal archive.

cartilage and multiple perforations of the subchondral bone of the two articular surfaces using 1.5-mm Kirschner wire. In addition, blood irrigation of the cortical surfaces lateral to the first metatarsal and medial to the second metatarsal was performed. The deformity was then reduced manually and evaluated under the image intensifier. Fixation was performed with two 4.5-mm partially threaded cannulated screws, with one passing from the medial wedge to the first metatarsal and the other passing from the base of the first metatarsal to the base of the second metatarsal. A 2.0-mm Kirschner wire was used between the first and the second metatarsals in the medial-diaphyseal region for neutralization. Bone fragments obtained from the medial exostosis were used as graft material at the fusion focus in the proximal space between the 1st and 2nd metatarsals, and images were obtained again with the intensifier to confirm the quality of the reduction achieved. Anteroposterior radiographs of the foot were then obtained with the knee flexed, as shown in figure 3.

The data obtained in this study were transferred into an MS-Excel spreadsheet, MS-Office 2013 version, and evaluated using the IBM SPSS (Statistical Package for Social Sciences) statistical package version 24.0. For descriptive and statistical analyses, we adopted a significance level of 5% (0.050) and applied the *Wilcoxon Signed-Rank test* and the *Mann-Whitney U test*, as shown in tables 1 to 4 and in figures 4 and 5.



Figure 3. A. Preoperative radiographic image of the right foot in the standing position. B. Immediate postoperative radiographic image with osteosynthesis.

Source: Author's personal archive.

RESULTS

Variability was analysed and differences in the “the angle to be corrected” were compared pre- and postoperatively, as shown in (Tables 1 to 4).

Tables 1, 2 and 3 show the results the *Wilcoxon Signed-Rank test*, which was applied to identify differences in the ABC variable between the two time points (pre- and postoperative) for the entire sample and for the moderate and severe cases separately.

Figures 4 and 5 schematically show the pre- and postoperative “the angle to be corrected” values for the total sample and for the moderate and severe cases.

Analysis of the entire patient sample showed a postoperative reduction in the “the angle to be corrected” from a mean of 10.29 degrees preoperatively to 3.83 degrees postoperatively, representing a statistically significant difference at $p < 0.001$, as shown in table 1.

Tables 2 and 3 show that preoperatively, the values in the moderate cases were lower than those in the severe cases, with minimum and maximum values of 5.50 and 13.00 degrees and 7.40 and 17.30 degrees, respectively; after surgery, these values were zero and 5.20 degrees for the moderate group and 1.20 and 11.60 degrees for the severe group, respectively. On average, the “the angle to be corrected” value in the moderate cases changed by 5.24 degrees and the value in the severe group changed by 6.97 degrees. Therefore, statistically significant differences were identified between the pre- and postoperative periods for both groups, with $p = 0.018$ in the moderate group and $p < 0.001$ in the severe group.

Table 4 shows the results of the *Mann-Whitney U test* comparing the moderate and severe groups preoperatively and then postoperatively and also comparing the results of the two time points. A statistically significant difference was identified preoperatively ($p = 0.007$), with lower values in the moderate cases than those in the severe cases. Postoperatively, the difference was not statistically significant ($p = 0.227$), indicating that the groups were statistically similar.

We achieved sesamoid dislocation correction across the total patient sample as reflected by postoperative angular reductions. Both moderate and severe cases showed statistically significant differences in angular correction after surgery, with $p = 0.018$ and $p < 0.001$, respectively.

DISCUSSION

Historically, use of the Lapidus technique^(17,18) has been limited due to the risk of complications, such as pseudarthrosis, malunion and shortening, but the technique has

Table 1. Differences in the ABC between the two observation time points for the entire sample

Variable pair	n	Mean	Standard deviation	Minimum	Maximum	25th Percentile	50th Percentile (Median)	75th Percentile	Sig. (p)
ABC [PRE]	24	10.29	2.67	5.50	17.30	7.95	10.40	12.15	<0.001
ABC [POST]	24	3.83	2.54	0.00	11.60	1.85	3.65	5.18	

ABC= angle to be corrected; PRE= preoperative; POST= postoperative.
Source: Prepared by the author based on the results of the study.

Table 2. Differences in the ABC between the two observation time points for the moderate cases

Variable pair	n	Mean	Standard deviation	Minimum	Maximum	25th Percentile	50th Percentile (Median)	75th Percentile	Sig. (p)
ABC [PRE]	7	8.03	2.38	5.50	13.00	6.80	7.70	8.40	0.018
ABC [POST]	7	2.79	1.94	0.00	5.20	0.80	3.60	4.40	

ABC= angle to be corrected; PRE= preoperative; POST= postoperative.
Source: Prepared by the author based on the results of the study.

Table 3. Differences in the ABC between the two observation time points for the severe cases

Variable pair	n	Mean	Standard deviation	Minimum	Maximum	25th Percentile	50th Percentile (Median)	75th Percentile	Sig. (p)
ABC [PRE]	17	11.22	2.22	7.40	17.30	9.60	10.90	12.35	<0.001
ABC [POST]	17	4.25	2.68	1.20	11.60	2.15	3.80	6.10	

ABC= angle to be corrected; PRE= preoperative; POST= postoperative.
Source: Prepared by the author based on the results of the study.

Table 4. Differences in the ABC between the considered degrees

Variable	Degree	n	Mean	Standard deviation	Minimum	Maximum	25th Percentile	50th Percentile (Median)	75th Percentile	Sig. (p)
ABC [PRE]	Moderate	7	8.03	2.38	5.50	13.00	6.80	7.70	8.40	0.007
	Severe	17	11.22	2.22	7.40	17.30	9.60	10.90	12.35	
	Total	24	10.29	2.67	5.50	17.30	7.95	10.40	12.15	
ABC [POST]	Moderate	7	2.79	1.94	0.00	5.20	0.80	3.60	4.40	0.227
	Severe	17	4.25	2.68	1.20	11.60	2.15	3.80	6.10	
	Total	24	3.83	2.54	0.00	11.60	1.85	3.65	5.18	

ABC= angle to be corrected; PRE= preoperative; POST= postoperative.
Source: Prepared by the author based on the results of the study.

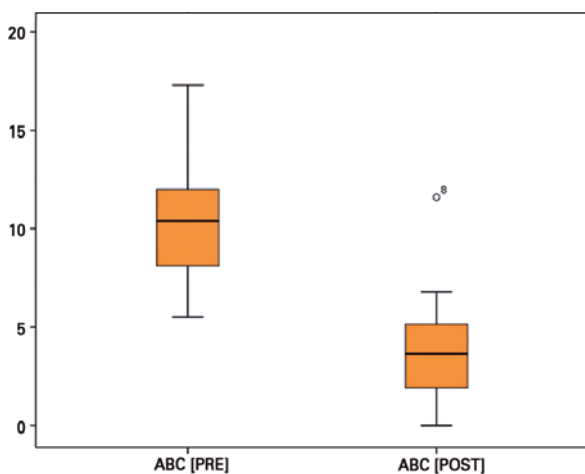


Figure 4. Representation of ABC values in the total sample pre- and postoperatively.
Source: Author's personal archive.

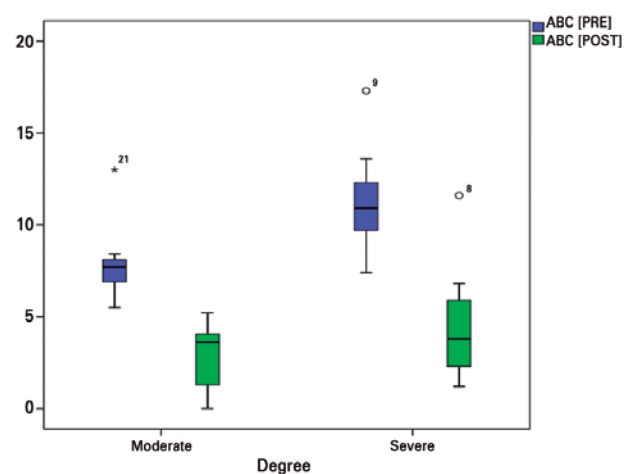


Figure 5. Representation of the total sample pre- and postoperatively by the degree of severity.
Source: Author's personal archive.

undergone some modifications to increase its stability and thus allow early weight-bearing without increasing the risk of postoperative complications⁽¹⁰⁾.

In 1992, Myerson et al.⁽¹⁹⁾ reported the results of 67 first cuneometatarsal joint arthrodesis procedures and documented a mean preoperative intermetatarsal angle of 14.3 degrees (9.5 to 34), which was corrected to a mean value of 5.8 degrees (0 to 12) postoperatively. Seven (10.4%) cases of pseudarthrosis were reported. Similar results were described by Catanzariti et al.⁽¹⁸⁾ in 1999.

In their 2013 work, Huang et al.⁽⁴⁾ showed that sesamoid dislocation correction is an important component of hallux valgus reconstruction as it minimizes the dynamic deforming force of the flexor hallucis brevis and prevents recurrence of the deformity.

In our study, sesamoid dislocation was evaluated by taking the tibial sesamoid's position in relation to the mechanical axis of the first metatarsal. Generally, a postoperative reduction in the ABC was achieved, from a mean of 10.29 degrees preoperatively to 3.8 degrees postoperatively, reflecting a statistically significant difference at $p < 0.001$.

In a similar study in 2016, Ortiz et al.⁽¹⁾ analysed interobserver variability between the "the angle to be corrected" and IMA and the IMA's ability to differentiate between groups that had previously been separated using the ABC as a reference. First, the authors concluded that the "the angle to be corrected" was easier and quicker to measure and therefore more reproducible. In the retrospective part of the study, they compared three groups of hallux valgus patients preoperatively and followed a predetermined protocol in which the surgical technique was indicated according to the ABC; that is, the Chevron technique was used for an "the angle to be corrected" between 1 and 5 degrees, the modified Scarf technique was used for an ABC between 6 and 9 degrees, and Poscow osteotomy was performed for "the angle to be corrected" greater than 10 degrees. As the authors expected, the ABC was effectively different ($p < 0.0001$) for each group, and the IMA could not differentiate between mild and moderate deformities.

The literature further shows that regarding this angle, although the reasoning is that in hallux valgus deformities, the sesamoid complex remains at the same location while the metatarsal deviates medially⁽²⁰⁾, the correct relationship between the metatarsal bone and sesamoid complex cannot be underestimated as incomplete reduction of the sesamoids is a major risk factor for hallux valgus recurrence⁽²¹⁾.

A retrospective cohort study⁽¹¹⁾ evaluated 136 patients undergoing modified Lapidus arthrodesis with conventional fixation using crossed screws. The patients were monitored for 12 months under an early weight-bearing pro-

tol. Significant improvements in the IMA and HVA were observed in the immediate postoperative period, with $p < 0.0001$ ⁽¹¹⁾. The IMA did not change significantly between the immediate and later postoperative periods, whereas the HVA increased by 1.1 degrees ($p < 0.001$), which can be partly explained by patients with recurrence of the deformity and also likely to load-bearing on the metatarsophalangeal joint in the later evaluation, whereas the immediate radiography was performed without load. This fact can be considered a bias in angular evaluation of sesamoid complex reduction, which may change when the patient is placed in the standing position.

As every patient with hallux valgus must be evaluated individually when selecting the technique to be used, several techniques must be available to treat each deformity appropriately⁽¹⁾. Using only one technique is insufficient, as it would not be able to correct all types of deformities⁽¹⁾. Therefore, the new "angle to be corrected" parameter will reasonably allow better patient stratification according to the correction required to move the first metatarsal back to its original, proper position (the centre of the sesamoid complex) and help the surgeon select the appropriate surgical technique according to correctional ability⁽¹⁾.

The objective of this study was achieved by correcting sesamoid dislocation in all patients in the sample as evidenced by angular reductions between the pre- and immediate postoperative periods. Both moderate and severe cases showed statistically significant differences in postoperative angular correction, with $p = 0.018$ and $p < 0.001$, respectively.

Ideally, the same analysis would be performed using radiographs in the standing position after bone healing to evaluate maintenance of the reduction achieved and possible complications such as pseudarthrosis in the late postoperative period. However, such an analysis cannot be performed at this time, and the study remains ongoing with follow-ups of these 24 feet.

CONCLUSIONS

Reduction in the "the angle to be corrected" was observed after cuneometatarsal arthrodesis surgery across the total patient sample, demonstrating a statistically significant difference. Both the moderate and severe cases showed effective postoperative angular correction. Comparing the pre- and postoperative results, a statistically significant difference was identified between these groups preoperatively, with lower values in the moderate cases than those in the severe cases. Postoperatively, the difference was not statistically significant ($p = 0.227$), indicating that the groups were statistically similar.

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