Böhler's Angle—Comparison Between the pre- and Postoperative in Displaced Intra-Articular Calcaneal Fractures*

Ângulo de Böhler—comparação entre o pré- e pós-operatório nas fraturas intra-articulares desviadas do calcanhar

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Abstract

Objective To compare pre- and postoperative variation of radiographic measurements of the Böhler angle (BA) in fractures with two types of deviations: severe and moderate.

Methods Pre- and postoperative BAs in 31 calcaneal fracture radiographs were retrospectively analyzed. A total of 4 patients were female (6.5%) and 26 were male (83.9%), with age ranging from 23 to 72 years old, and a mean age of 44.5 years old.

Results The results show that the postoperative BA was significantly larger than the preoperative BA ($p = 0.000$). At the intraevaluator and overall assessments, the postoperative BA was, on average, 10.6° higher than the preoperative measure. The postoperative angle was, on average, 108% higher than the preoperative angle. In the global assessment, the agreement between evaluators was excellent, both regarding the estimated point value (0.98) and the intraclass correlation (ICC) confidence interval (CI).

Conclusion In the global analysis, the postoperative BAs were, on average, significantly higher than the preoperative measurements. The farther from the normal range (20° to 40°) the preoperative angle is, the greater the difference after the surgery. When the preoperative angle was normal, the postoperative angle was, on average, 1.28 times the preoperative measurement. If the preoperative BA was abnormal, the postoperative angle was, on average, 17.3 times the preoperative measurement. It was demonstrated that more severe fractures present better anatomic results when compared with moderate fractures. The present study also confirms a good interobserver correlation for the BA.

Keywords
- calcaneus
- bone fractures
- intra-articular fractures
- radiography

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Resumo

Objetivo Comparar a variação dos resultados das medidas radiográficas do ângulo de Böhler, no pré e pós-operatório, em fraturas com dois tipos de desvio: graves e moderadas.

Métodos O ângulo de Böhler foi analisado retrospectivamente em 31 radiografias pré e pós-operatórias de fraturas do calcâneo. Quatro pacientes eram do sexo feminino (6,5%) e 26 do masculino (83,9%), entre 23 e 72 anos, média de 44,5.

Resultados As medidas pré e pós-operatória demonstraram que o ângulo de Böhler após a cirurgia foi significativamente maior do que o ângulo de Böhler pré-operatório (p-valor = 0,000). Nas análises intraobservador e global, o ângulo de Böhler pós-operatório foi, em média, 10,6 graus maior do que no pré-operatório. O ângulo pós-operatório foi, em média, 108% maior do que o ângulo pré-operatório. No global, a concordância entre os avaliadores é excelente, tanto em relação ao valor pontual estimado (0,98) quanto em relação ao intervalo de confiança do ICC.

Conclusão Na análise global, verificou-se que as medidas do ângulo de Böhler no pós-operatório são, em média, significativamente maiores do que as do ângulo pré-operatório. Quanto mais distante da faixa de normalidade (20 a 40 graus) estiver o ângulo pré-operatório, maior a diferença no ângulo após a cirurgia. Quando o ângulo pré-operatório está na faixa de normalidade, o ângulo pós-operatório será, em média, 1,28 vez o ângulo pré-operatório; se o ângulo de Böhler pré-operatório estiver fora da faixa de normalidade, o ângulo pós-operatório será, em média, 17,3 vezes o ângulo pré-operatório. Ficou demonstrado que as fraturas mais graves apresentam melhores resultados anatômicos quando comparadas com as fraturas moderadas. O estudo também confirmou uma boa correlação interobservador para o ângulo de Böhler.

Palavras-chave
- calcâneo
- fraturas ósseas
- fraturas intra-articulares
- radiografias

Introduction

The calcaneus is the most frequently traumatized bone, and represents 60% of the hindfoot fractures. These fractures comprise ~ 1 to 2% of all fractures, and approximately 75% present an intra-articular component, with important consequences for the patients.[1]

The Böhler angle (BA) is the complementary angle formed by two lines: (a) a line between the highest region of the anterior process and the highest part of the posterior articular surface and (b) a line between the same point on the posterior articular surface and the most superior point of the calcaneus tuberosity. The BA usually ranges from 20° to 40°.[2–6] It is often used in profile radiographs to assess the degree and severity of intra-articular deformity deviated from the calcaneus, and it helps to confirm the outcome of the reduction in postoperative radiographs.[7–11] Some authors suggest that the restoration of the BA improves outcomes and indicate its prognostic value in the postoperative period of the fracture and in the subtalar joint arthrodesis.[2–6,12,13]

According to the literature, the BA assists the clinical outcome by correlating the variations between preoperative and postoperative measurements.[8–11] Knight et al[14] have shown that papers on BA have good intraobserver reliability. The present study aims to compare the BA variation in pre- and postoperative radiographic measurements in fractures with severe and moderate deviation.

Material and Methods

From April 2015 to June 2017, 31 pre- and postoperative radiographs of calcaneal fractures were retrospectively analyzed. The present study was submitted to and authorized by the Ethics Committee of the Hospital and informed consent forms were not required since data were extracted from medical records and radiographs.

The inclusion criteria were deviated calcaneal fractures, age > 18 years old, and treatment within 3 weeks after the fracture. The exclusion criteria were incomplete or poor quality radiographs, previous or pathological fractures, open fractures, medical contraindication for surgery, and calcaneal fractures with concomitant involvement of the ankle or foot bones. All of the procedures were performed through the extended lateral approach.

The BA was measured on pre- and postoperative radiographs of patients with calcaneal fractures. Angles between 20° and 40° were considered within an acceptable limit, and the measurements were analyzed by 2 independent researchers (3rd year medical residents).

The study sample consisted of 31 patients, 4 females (6.5%) and 26 males (83.9%). Among the 31 patients, 1 had no recorded information on gender and age. The frequency distribution of the age of the patients by gender and the global distribution are shown in ►**Table 1**, and the age distribution is shown in ►**Table 2**. Patients were between 23 and 72 years old, with a mean age of 44.5 years old, a

Table 1 Age frequency distribution of the patients

Age (years old)	Global		Female		Male	
	Absolute frequency	Relative frequency	Absolute frequency	Relative frequency	Absolute frequency	Relative frequency
22–30	3	10.0%	1	25.0%	2	7.7%
31–39	6	20.0%	0	0.0%	6	23.1%
40–48	13	43.3%	0	0.0%	13	50.0%
49–57	6	20.0%	2	50.0%	4	15.4%
58–64	0	0.0%	0	0.0%	0	0.0%
65–73	2	6.7%	1	25.0%	1	3.8%

Table 2 Main statistical values regarding the distribution of the age of the patients

Mean	Median	SD	Minimum	Maximum	CV
44.5	46.0	11.3	23.0	72.0	0.25

Abbreviation: CV, coefficient of variation; SD, standard deviation.

median age of 46 years old, standard deviation (SD) of 11.3, and coefficient of variation of 0.25, evidencing moderate age variability. The age group was of between 40 and 48 years old, concentrating 43.3% of the sample.

Methodology

The variables of the present study are BA measurements made by two evaluators from radiographic examinations of severe and moderate deviated calcaneal fractures. The collected data constituted a database analyzed with IBM SPSS Statistics for Windows, Version 22.0 (IBM Corp., Armonk, NY) and with Microsoft Excel 2007 (Microsoft Corporation, Redmond, WA, USA).

For the sample characterization and the descriptive analysis of the behavior of the variables, data were synthesized through descriptive statistics (mean, median, minimum, maximum, SD, and coefficient of variation [CV]), descriptive graphs, and frequency distributions. The distribution variability of one variable was considered low if $CV < 0.20$; moderate if $0.20 \leq CV < 0.40$; and high if $CV \geq 0.40$.

In the inferential analysis, the normality hypothesis of measurement distribution was verified by the Kolmogorov-Smirnov test and by the Shapiro-Wilk test. The test distribution was considered normal when both tests consistently concluded so. The preoperative BA measurements were compared with the postoperative values, and both were compared between the two evaluators. When the two measures had normal distributions, they were compared in pairs by a paired Student-t test. When at least one of the measures did not have normal distribution, the two paired measures were compared using the Wilcoxon test.

The agreement analysis was performed between the measurements of the two evaluators by quantifying the raw agreement (percentage of cases in which the two measurements are equal, that is, in which D, the difference between the two measures, is equal to 0) and the intraclass correlation coefficient (ICC). The ICC expresses the total variability proportion, which is due to the variability between units. In assessing the agreement between 2 measures, such as the agreement between the angle measured by evaluator 1 and evaluator 2, the ICC can be interpreted as a measure of agreement, as it determines the distance between the 2 measurements and a 45° straight line to which agreement would be perfect, since both measures would be equal. The ICC was calculated in the two-way mixed analysis of variance (ANOVA) model, and the study interest was "consistency analysis". The ICC agreement was classified as follows:

$0.00 \leq ICC \leq 0.20$ = poor agreement
$0.20 < ICC \leq 0.40$ = reasonable agreement
$0.40 < ICC \leq 0.60$ = good agreement
$0.60 < ICC \leq 0.80$ = very good agreement
$0.80 < ICC \leq 1.00$ = excellent agreement

The imprecision estimative from the ICC was analyzed by its confidence interval (CI) at the 95% level, while significance was evaluated by an ICC F test. The agreement was considered significantly good if the ICC was significantly non-zero and if its point value and all of the CI values at a 95% confidence level were at least at the "good agreement" level.

All of the discussions considered a maximum significance level of 5% (0.05), that is, the null hypothesis was rejected whenever the test-associated *p-value* was < 0.05. In tests with asymptotic and exact *p-value*, the latter was considered.

Results

Descriptive Analyses of Angle Measurements

►**Table 3** shows the *p-values* of the normality tests for BA distributions measured by the two evaluators and for the overall distribution (i.e., regardless of the evaluator). Since all of the *p-values* were > 5.0%, it is concluded that all of the BA measurements, both pre- and postoperative, either from the 2 evaluators or the overall values, follow normal distribution. Therefore, any inferential analysis comparing BAs used the parametric approach.

The main statistics of the distributions of pre- and postoperative BA measurements for each evaluator and the global distribution (regardless of the evaluator) are shown

Table 3 Normality tests for pre- and postoperative Böhler angle distribution for each evaluator and global distribution

Evaluator	Angle	*p-value* for the Kolmogorov-Smirnov test	*p-value* for the Shapiro-Wilk test	Normal distribution
1	Pre	0.200	0.196	Yes
	Post	0.200	0.987	Yes
2	Pre	0.200	0.361	Yes
	Post	0.200	0.922	Yes
Global	Pre	0200	0.051	Yes
	Post	0.200	0.936	Yes

in ►**Table 4**. Since all of the CVs were > 0.20, the BA measurements present high sample variability. The BA distributions according to each evaluator and the global distribution are shown in the boxplot graphs in ►**Fig. 1**. The boxplot of postoperative angle measurements from evaluator 2 shows that the maximum value of 50° is an outlier, a discrepant value (○) from the other patients. The graphs and statistics demonstrate that the angle increased after the surgery, and that the effect is significant. A paired Student–t test for pre- and postoperative measurements showed that the postoperative BAs are significantly higher than the preoperative BAs ($p = 0.000$ in all comparisons).

According to both evaluators and at the overall analysis, the postoperative BA value is, on average, 10.6° higher than in the preoperative period. The statistics of the angle differences, both per evaluator and at the overall analysis, is shown in ►**Table 5**. For 2 observations from evaluator 1, the postoperative angle was smaller than the preoperative angle. The variability of the difference between angles is very high (CV > 0.80), and the largest differences found, > 40°, are very atypical and constitute outliers in the distributions (►**Fig. 2**). The differences between the measurements of the angles do not follow a normal distribution, since they presented *p-values* < 5% for both normality tests and both evaluators. Comparing the differences between pre- and postoperative BA values according to 2 evaluators by the Wilcoxon test, $p = 0.761$ was obtained. It was concluded, therefore, that there was no significant difference between the variations of the angles from the two evaluators.

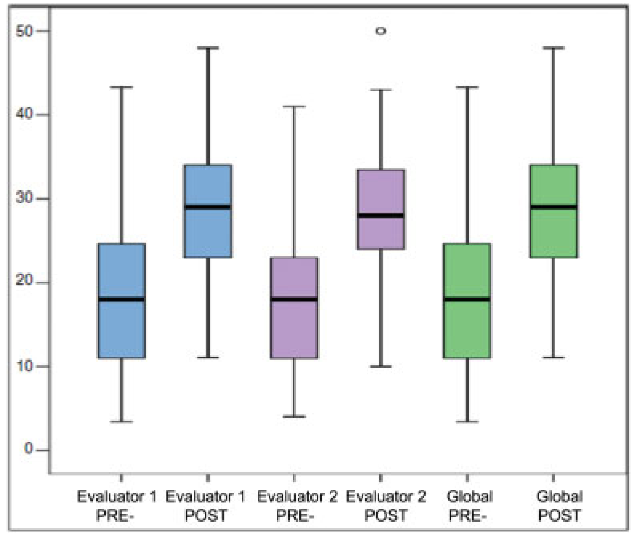

Fig. 1 Distributions of pre- and postoperative Böhler angle measurements for each evaluator and global distribution.

►**Table 6** shows the statistics of the difference between both angles, relative (percentage) to the preoperative value, per evaluator and globally. For the evaluators and at the overall analysis, the postoperative angle is, on average, 108.1% higher than the preoperative angle. The variability of the relative difference between both angles is very high (CV > 1.5), and the largest differences found, > 40°, constitute outliers in the evaluation distributions. The boxplots of the relative differences between the pre- and postoperative angles are shown in ►**Fig. 3**. ►**Fig. 4** shows that the differences > 250% of the preoperative angle are atypical, outliers at the distribution. The relative differences between the angle measurements do not follow normal distribution, since they presented *p-values* < 5% at both normality tests and for both evaluators. When comparing the relative differences between the pre and postoperative angles from both evaluators by the Wilcoxon test, the *p-value* was 0.666, leading to the conclusion that there was no significant difference between the relative angle variations between the 2 evaluators.

Table 4 Main statistical values regarding pre- and postoperative Böhler angle distribution for each evaluator and global distribution

Evaluator	Evaluation	Mean	Median	Minimum	Maximum	SD	CV	*p-value*
1	Pre	18.5	18.0	3.4	43.3	9.4	0.51	0.000
	Post	28.9	29.0	11.1	48.0	8.3	0.29	
2	Pre	18.2	18.0	4.0	41.0	8.9	0.49	0.000
	Post	28.8	28.0	10.0	50.0	8.8	0.31	
Global	Pre	18.4	18.0	3.4	43.3	9.1	0.49	0.000
	Post	29.0	29.0	10.0	50.0	8.5	0.29	

Abbreviation: CV, coefficient of variation; SD, standard deviation.
a A paired Student-t test compared pre- and postoperative measurements.

Table 5 Main statistical values regarding the difference between pre- and postoperative Böhler angle measurements for each evaluator and global distribution

Evaluator	Mean	Median	Minimum	Maximum	SD	CV
1	10.6	9.8	−2.5	42.5	9.2	0.87
2	10.6	8.0	1.0	46.0	8.6	0.81
Global	10.6	8.0	−2.5	46.0	8.8	0.83

Abbreviation: CV, coefficient of variation; SD, standard deviation.

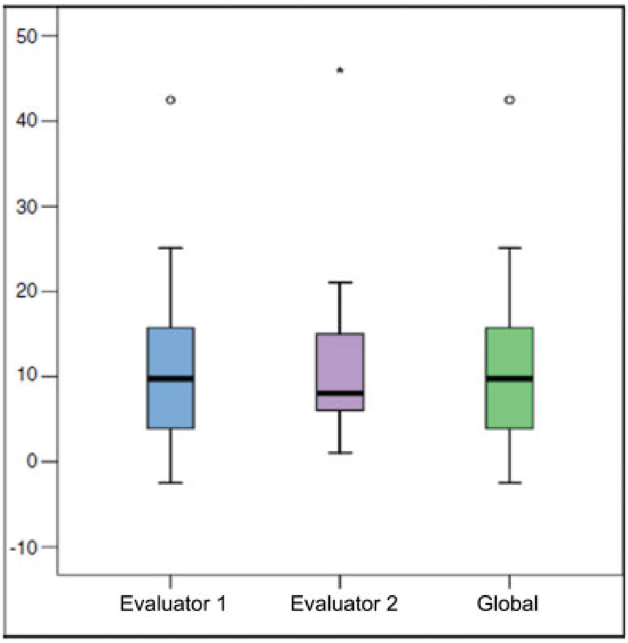

Fig. 2 Distributions of pre- and postoperative Böhler angle measurement differences for each evaluator and global distribution.

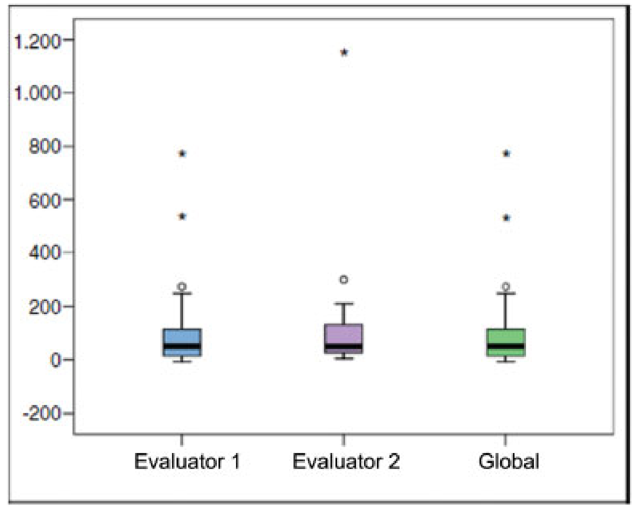

Fig. 3 Distributions of pre- and postoperative Böhler angle measurement relative differences (%) for each evaluator and global distribution.

►**Fig. 4** also shows the relationship between the relative angle difference and the preoperative BA measurements according to evaluators 1 and 2. The graph shows an inverse function curve that explains well the behavior of the two variables as [(R)]2 > 0.50.

►**Fig. 5** shows the relationship between the relative angle difference and the preoperative BA measurement at the overall analysis with no evaluator discrimination. The overall relationship between the relative angle difference and the preoperative BA measurement is also well explained by an inverse function as [(R)]2 = 0.50.

►**Figs. 4** and **5** and the data show the relative postoperative angle difference is higher for smaller preoperative angles and decreases as the preoperative angle increases. The farther the preoperative angle is from the normal range, from 20° to 40°, the greater the relative postoperative angle difference. When the preoperative angle is within the normal range of 20° to 40°, the relative BA difference ranges from 6.0 to 80.0%, with a low variability around the mean difference of 28.0%. When the preoperative angles are outside the normal range, the relative BA difference ranges from -6.0 to 1,150.0%, with a high variability around the mean difference of 163.2%. That is, if the preoperative BA value is in the normal range, the postoperative angle will be, on average, 1.28 times the preoperative value; if the preoperative BA value is outside the normal range, the postoperative BA value will be, on average, 17.3 times the preoperative angle.

Agreement Analysis between Evaluators

►**Table 7** shows the agreement analysis between the angle measurements performed by two evaluators. Regarding absolute agreement, both evaluators assigned the same

Table 6 Main statistical values regarding the difference between pre- and postoperative Böhler angle measures in relation to the pre-operative angle for each evaluator and global distribution

Evaluator	Mean	Median	Minimum	Maximum	SD	CV
1	108.1%	50.6%	−5.8%	772.7%	165.3%	1.52
2	108.9%	50.0%	4.9%	1150.0%	165.3%	1.51
Global	108.5%	50.3%	−5.8%	1150.0%	185.0%	1.70

Abbreviation: CV, coefficient of variation; SD, standard deviation.

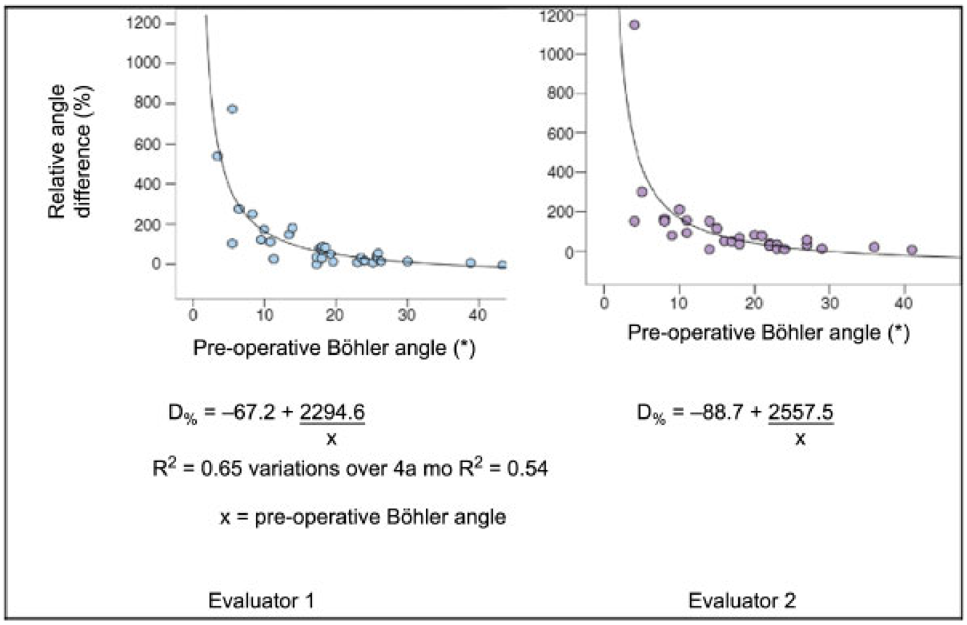

Fig. 4 Relationship between the relative angle difference and the preoperative Böhler angle measurement for evaluators 1 and 2.

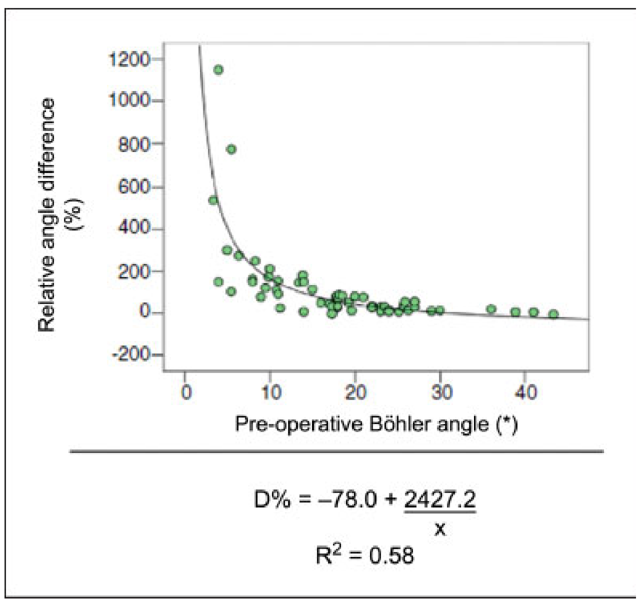

Fig. 5 Relationship between the relative angle difference and the preoperative Böhler angle measurement, global evaluation.

measurement to the angle in only one case. However, the difference between measurements from the 2 evaluators did not exceed 4° in the preoperative analysis and 6° in the postoperative analysis. Overall, the agreement between the evaluators is excellent, both regarding the estimated point value, equal to 0.98, and the ICC CI, fully within the excellent agreement range, from 0.8 to 1.0. At the pre- and postoperative measurements, point and interval ICC estimates show excellent agreement between the two evaluators. The *p-values* of the F tests for ICC values are not reported here, but all of them were < 0.0001, indicating that the ICC values are all significantly non-zero. Corroborating the results of the excellent agreement analysis between the two values, the *p-values* of the Student-t test comparing the measurements from both evaluators were all $> 5.0\%$, showing that there was no significant difference between the angle measurements from both evaluators. The agreement analysis between the two evaluators showed that their angle assessments were different, but not significantly, presenting the same level of measurement expertise.

Discussion

Based on the results of the statistical analysis of the present study in 31 patients with deviated calcaneal fractures, it was found that a higher preoperative BA value, which would mean a fracture with less deviation, had an average variation of 28% (6.0 to 80.0%), and was associated with a postoperative

Table 7 Agreement analysis between the angles measured by both evaluators during pre- and postoperative evaluations and global distribution

Measure source	Böhler-Evaluator 1 *vs* Evaluator 2				Measure variation from both evaluators	*p-value* for the paired Student-t test
	ICC	CI for ICC	Agreement classification	Raw agreement		
Preoperative (31 evaluations)	0.98	0.95–0.99	Excellent	1 (3.2%)	0.0–4.0	0.457
Postoperative (31 evaluations)	0.96	0.92–0.98	Excellent	0 (0.0)	0.8–6.0	0.595
Both measures (62 evaluations)	0.98	0.96–0.99	Excellent	1 (1.6%)	−6.0–4.0	0.370

Abbreviations: CI, confidence interval; ICC, intraclass correlation coefficient.

angle 1.28 times higher. However, the lower the preoperative BA, which would mean a fracture with greater deviation, had a mean variation of 162.2% (ranging from 6.0 to 1,150.0%), and it was associated with a postoperative angle 17.3 times higher. It has been shown that the surgeon tends to anatomically reduce more severe fractures than those with minor deviations. The present study has also confirmed a good interobserver correlation for BAs.

Most of the literature analyzing the BA emphasizes angle restoration and prognosis significance. Although some authors suggest that BA restoration may have no effect on outcomes, most studies show that BA restoration guides anatomical reduction and improves outcomes.[10,15–24] Similarly, there is great evidence in the literature that a very low initial BA angle in calcaneal fractures is a prognostic factor and a predictor of poor outcome.[10,20,25,26]

The present study used a cutoff angle of $\leq 20°$ to define most severe fractures based on Isaacs et al,[27] who proved that the BA is most accurate in determining the presence or absence of fracture. Their observations suggest that BA accuracy can make it suitable as a screening tool in the diagnosis of calcaneal fracture. They have also demonstrated another important aspect, that the cutoff angle of $\leq 20°$ is independent of the angle before the fracture. Consequently, it would not be necessary to measure the BA value on the contralateral side in patients with calcaneal fractures.

Although the literature has demonstrated that the BA has good credibility, many classifications and measures are deemed unreliable.[28–31] The most common justifications include lack of observer training, nonuniform and poor quality radiographic images, and vague and inaccurate ratings. Another source of difficulty for angle measurement may be an overlap of the synthesis material to the reference points in the postoperative period. Otero et al[32] demonstrated that even with trained observers and with an adequate configuration in BA radiographic measurement, interpretation differences are common. Gonzalez et al[33] found a 6° error measurement for BA. Two factors that increased error included a low level of observer training, such as increased obliquity on lateral radiographs. These authors observed that this difference was only seen when the radiography was made with a very oblique angle (anterior at 20° and caudal at 15°). In order to avoid discrepancies and to minimize potential risks of BA measurement failures, the measurements were previously defined, using properly trained observers and a measurement protocol; moreover, the performance of the evaluators was tested, and radiographs with low quality for measurements were excluded.

As described by Bland and Altman,[34] repeated measurements on the same subject range around a true value, since the measurement error and the SD of repeated measurements allows the determination of the error size. In our study, we have used the CV, that is, the measure used to estimate the experimental accuracy, and we have verified that BA measurements presented high variability among the 31 evaluated patients. The results demonstrated, both for the evaluators and the overall sample, that the angle increased significantly after the surgery. The postoperative angle was, on average, 10.6° higher than in the preoperative period, and there was no significant difference in the variation of the angles among observers ($p = 0.761$). It is noteworthy that the relative difference observed in the postoperative BA value was higher for lower preoperative angles, and that it decreases as the preoperative angle increases. The more distant the preoperative angle is from the normal range, from 20° to 40°, the greater the relative difference after the surgery. When the preoperative angle is within the normal range of 20° to 40°, the relative BA difference assumes values of 6.0 to 80.0%, with low variability around the mean difference of 28.0%. When the preoperative angles are outside the normal range, the relative BA difference assumes values of -6.0 to 1,150.0%, with a high variability around the mean difference of 163.2%. That is, if the preoperative BA is in the normal range, the postoperative angle will be, on average, 1.28 times the preoperative angle; if the preoperative BA is outside the normal range, the postoperative BA will be, on average, 17.3 times the preoperative angle.

The ICC estimates the fraction of the total variability of measures due to variations between individuals. Otero et al[32] did not observe a significant difference in the ICC for the inter- or intraobserver BA measurement in both preoperative and postoperative radiographs. The present study showed that the difference between measurements did not exceed 4° in the preoperative measurement and 6° in the postoperative measurement by analyzing the agreement between results from the 2 evaluators. Overall, the agreement among the evaluators was excellent (equal to 0.98). In the pre- and postoperative measurements, estimates of point and interval ICC show excellent agreement between the two evaluators.

There are some limitations in the present study that may have influenced the results. It was a retrospective study with a small number of evaluators, with radiographs made for daily clinical care instead of research purposes, which could alter and affect angle measurements. Therefore, we have excluded some radiographs that could generate measurement doubts. An intraobserver analysis was not performed.

Conclusion

In the present study, the BA was evaluated at two moments, pre- and postoperative, by two evaluators. In the overall analysis, the postoperative BA measurements were, on average, significantly higher than the preoperative values. The relative difference observed in the angle after the surgery was higher for lower preoperative angle values and decreases as the preoperative values increases. The farther the preoperative angle was from the normal range, from 20° to 40°, the greater the angle difference after the surgery. When the preoperative angle was within the normal range of 20° to 40°, the postoperative angle was, on average, 1.28 times the preoperative angle; if the preoperative BA value was outside the normal range, the postoperative angle was, on average, 17.3 times the preoperative angle. Most severe fractures present better anatomical outcomes when compared with moderate fractures. The present study has also confirmed a good interobserver correlation for BA.

Conflicts of Interest
The authors have no conflicts of interest to declare.

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