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ORIGINAL ARTICLE

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Intra and interobserver analysis of the Sanders classification for calcaneal fractures

Avaliação intraobservador e interobservador da classificação de Sanders para fraturas de calcâneo

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ABSTRACT

Objective: To evaluate the intra and interobserver variation in the Sanders classification of calcaneal fractures and the clinical-radiological correlation of postoperative X-ray images and computed tomography (CT) scans.

Methods: We sent pre- and postoperative images in the form of a questionnaire to 18 foot and ankle surgeons with varying experience and examined evaluations of the postoperative reduction and Sanders classification quality criteria of 12 calcaneal fractures. The kappa (K) values were calculated and compared to those in the literature, and the quality of the reduction was compared to the patient's American Orthopaedic Foot and Ankle Society Ankle-Hindfoot Scale (AOFAS-AHS) score.

Results: The mean intraobserver K of the Sanders classification was 0.49. Disregarding the subclasses, the intraobserver K was 0.55, and when type III and IV fractures were grouped, the intraobserver K was 0.57. The interobserver K values in these same three conditions were 0.22, 0.20, and 0.21, respectively. We also observed that the group of less experienced surgeons showed better intraobserver K values than the more experienced surgeons. In the analysis of the reduction quality based on X-ray images and the AOFAS-AHS score of the patient, we found a value of p=0.043.

Conclusion: The K values were consistent with previous studies, confirming moderate intraobserver reproducibility and acceptable interobserver reliability. We also confirmed the presence of a significant relationship between the reduction quality based on X-ray images and the AOFAS-AHS score of the patient.

Level of Evidence III; Diagnostic Studies; Nonconsecutive patients, no uniformly applied reference gold standard.

Keywords: Fractures, bone; Calcaneus; Diagnostic imaging; Surgery, Reproducibility of Results.

RESUMO

Objetivo: Avaliar a variação intra e interobservador da classificação de Sanders para fraturas de calcâneo e a correlação clínico radiológica de imagens de RX e TC pós-operatórias.

Métodos: Enviamos imagens pré e pós-operatórias a 18 cirurgiões de pé e tornozelo, com tempo de experiência variado, na forma de questionário. Obtivemos respostas sobre os critérios de qualidade da redução pós-operatória e a classificação de Sanders de 12 fraturas do calcâneo. Os valores Kappa foram calculados, comparados com a literatura e a qualidade da redução foi comparada com o AOFAS-AHS do paciente.

Resultados: O K intraobservador médio da classificação de Sanders foi 0,49. Desconsiderando-se as subclasses o K intraobservador foi 0,55 e ao juntar as fraturas tipo III com tipo IV foi 0,57. Já os valores K interobservador foram, nessas mesmas três situações, 0,22, 0,20 e 0,21, respectivamente. Observamos também que o grupo de cirurgiões menos experientes apresentou melhor K intraobservador do que os mais experientes. Encontramos ainda valor p=0,043, quando relacionamos à qualidade da redução pelo RX e o AOFAS-AHS do paciente.

Work performed at the Hospital Risoleta Tolentino Neves e Hospital Madre Teresa, Belo Horizonte, MG, Brazil.

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Conclusão: Os valores K estão de acordo com estudos prévios, confirmando reprodutibilidade intraobservador moderada e confiabilidade interobservador aceitável. Também confirmamos a presença de relação estatística significativa entre qualidade da redução no RX e o AOFAS-AHS do paciente.
Nível de Evidência III; Estudos Diagnósticos; Pacientes não consecutivos, sem padrão ouro de referência aplicado uniformemente.

Descritores: Fraturas ósseas; Calcâneo; Diagnóstico por imagem; Cirurgia; Reprodutibilidade dos testes.

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INTRODUCTION

Calcaneal fractures have an incidence of 11.5 per 100,000 persons/year and are 2.4 times more common in males; 65% of calcaneal fractures are intra-articular. The peak incidence occurs between 20 and 29 years of age in men, and in women, the overall incidence is 6.26 per 100,000 persons/year, with a gradual increase in incidence after menopause[(1)].

In addition to the severity of calcaneal fractures, an important correlation exists between the prognosis and the surgeon's experience. Sanders et al.[(2)] showed an increase in good and excellent results with increasing treatment experience (1987, 27%; 1988, 54%; 1989, 74%; 1990, 84%). In the same study, Sanders et al. presented their tomographic and prognostic classification of intra-articular calcaneal fractures; this classification is currently one of the most commonly used classification methods[(3)]. The Sanders classification is based on the involvement of the posterior facet of the subtalar joint and is evaluated based on coronal computed tomography (CT) scans. Numerals I, II, and III represent the number of displaced fragments, and type IV includes fractures with 4 or more displaced fragments. The letters A, B, or C represent the position of the fracture line(s), from lateral to medial[(4)].

Recent meta-analyses have demonstrated the superiority of surgical treatment over conservative treatment for calcaneal fractures with regard to the functional outcome, despite the higher incidence of infections or reoperations associated with surgical treatment[(5,6)]. In contrast, patients treated conservatively presented greater difficulties wearing shoes, hindfoot stiffness, and a later return to work[(5)]. Patients treated surgically had a 4-fold higher risk of requiring subtalar arthrodesis for Sanders type III fractures than those with type II fractures, confirming the prognostic value of the classification[(4)].

Given the need for improvements in fracture diagnosis and classifications and how this will be reflected by clearer and more effective choices of surgical techniques, the reproducibility and reliability of the Sanders classification is still under study. In this context, the objective of this study was to evaluate the intraobserver reproducibility and the interobserver reliability of the Sanders classification in a group of 18 foot and ankle surgeons and to correlate the results with their levels of experience. In contrast to similar studies, no previous clarifications on the classification were provided to the surgeons. In addition, comparative analyses were performed between the fracture reduction quality obtained and the American Orthopaedic Foot and Ankle Society Ankle-Hindfoot Scale (AOFAS-AHS) functional score.

METHODS

This study was approved by the Ethics Committee and registered in the Brazil Platform (Plataforma Brazil) under CAAE No. 01935918.2.0000.5127.

All patients were informed about the study and its policies regarding human rights and signed an informed consent form.

Twelve calcaneal fractures surgically treated between 2015 and 2017 in two hospitals in Belo Horizonte, Brazil, by two experienced surgeons were evaluated. The inclusion criteria included obtaining all required documentation, X-ray images, and CT scans of the pre- and postoperative period, in addition to having complete data for the study present in the medical records, including the AOFAS-AHS score.

The surgical technique involved mini-access to the tarsal sinus with plate osteosynthesis and 3.5-mm cortical screws or with 4.5-mm cannulated screws alone. These patients were followed-up, and the examinations used for postoperative monitoring were performed at a minimum of 1 year after the osteosynthesis (minimum of 12 months and maximum of 19 months), when the AOFAS-AHS questionnaire was also applied (functional classification system, scored from 0 to 100, with higher values representing a better result[(7)]).

A digital questionnaire was sent to 18 foot and ankle surgeons with varying levels of experience in the field who were blinded to the patients and surgical outcomes. They classified the fracture using the Sanders classification and answered questions on the reduction quality obtained in the same fractures that they had classified, based on the postoperative profile, axial X-ray images of the calcaneus, and two postoperative coronal CT scans equivalent to those used by Sanders et al. to classify fractures. Each pre- and postoperative coronal CT scan included the longest length of the inferior facet of the talus at the level of the sustentaculum, which was carefully selected by the authors. The two preoperative CT scans were included in the questionnaire twice, once at the beginning and once at the end, to assess the intraobserver variation and the interobserver agreement of the Sanders classification. It was not possible to return to a previous question, and no type of training on the Sanders classification was previously provided. In addition to the eight options of the Sanders classification, the respondent could choose a ninth option that indicated that the images were inadequate to classify the fracture. Four response options were given to evaluate the quality of the reduction and were transformed into scores of 0 to 6 for statistical analysis (0 - unacceptable, 2 - poor, 4 - satisfactory, and 6 - anatomical reduction).

Statistical analysis

The interobserver reliability and reproducibility were evaluated using the kappa (K) statistic, which was generated using SPSS version 25.0 for Windows (SPSS Inc. Chicago, IL, USA). The K value measures the agreement between answers, disregarding the possibility of equality occurring by chance. A K value equal to 0.00 represents chance, whereas a value of 1.00 represents perfect agreement. The K values were interpreted according to Landis and Koch[8]. In this interpretation, values lower than 0.00 indicate poor agreement; values from 0.00 to 0.20 indicate slight agreement; values from 0.21 to 0.40 indicate fair agreement; values from 0.41 to 0.60 indicate moderate agreement; values from 0.61 to 0.80 indicate good or substantial agreement; and values from 0.81 to 1.00 indicate excellent agreement. We calculated the K values for three scenarios: the original Sanders classification system; when the subclasses were disregarded; and combining type III type IV fractures. The other responses were analyzed with the chi-square test, and a value of $p<0.05$ was considered statistically significant.

RESULTS

Of the 18 foot and ankle surgeons who answered the questionnaire, three (16.67%) had more than 20 years of experience in foot and ankle surgery, two (11.11%) had 10 to 20 years of experience, two (11.11%) had between 5 and 10 years of experience, and 11 (61.11%) had 1 to 5 years of experience. Of these, six (33.33%) surgeons performed foot and ankle surgeries 100% of the time, six performed surgeries between 75 and 99% of the time, five performed surgeries from 50 to 75% of the time, and one performed surgeries less than 50% of the time. Of the 12 fractures analyzed, the patients included eight men (nine fractures) and three women, with five fractures on the left side and seven on the right side, with a mean age of 44.5 years (31 to 59).

Tables 1 and 2 provide the criteria that each examiner considered in the analysis of the X-ray and postoperative CT scans of calcaneal fractures.

Table 1. In an X-ray image, which criteria do you use to judge osteosynthesis as being satisfactory?

Radiographic criteria considered	Number of evaluators
Restored calcaneus axial alignment	17 (94.44%)
Anatomically reduced articular surface	17 (94.44%)
Absence of intra-articular implant	17 (94.44%)
Reestablished Bohler angle	15 (83.33%)
Absence of calcaneal enlargement	15 (83.33%)
Reestablished calcaneal length	13 (72.22%)
Reestablished Gissane angle	11 (61.11%)
Absence of "lost synthesis"	3 (16.67%)
Number of screws used	3 (16.67%)

Percentage in parentheses

Source: Prepared by the author based on the results of the research.

Table 2. In a CT scan, which criteria do you use to judge osteosynthesis as being satisfactory?

Tomographic criterion considered	Number of evaluators
Absence of intra-articular implant	17 (94.44%)
Anatomically reduced articular surface	16 (88.89%)
Parallelism between the articular facets of the subtalar joint	14 77.78%)
Articular step-off <2 mm	12 (66.67%)
Absence of subtalar widening	12 (66.67%)
Reestablished calcaneal length	8 (44.44%)
Articular step-off <1 mm	6 (33.33%)
Absence of "lost synthesis"	2 (11.11%)
Number of screws used	1 (5.56%)

Percentage in parentheses

Source: Prepared by the author based on the results of the research.

Table 3. Intra and interobserver agreement of the Sanders classification

Agreement	K
Intraobserver without subclasses and III + IV	0.57
Intraobserver without subclasses	0.55
Intraobserver with subclasses	0.49
Interobserver without subclasses and III + IV	0.21
Interobserver without subclasses	0.20
Interobserver with subclasses	0.22

Source: Prepared by the author based on the results of the research.

After analyzing the individual responses and disregarding images that the examiners judged to be inadequate, we calculated the K values shown in table 3. The intraobserver reproducibility in the three scenarios studied was within the value range considered moderate (K between 0.4 and 0.6). The interobserver agreement was in the acceptable range of K values, ranging from 0.20 to 0.22 in the three scenarios. Next, we compiled the results found in the literature and created table 4.

Table 5 shows the evaluation of reproducibility and the agreement obtained, stratified by the duration of experience and percentage of foot and ankle surgery performance of the surgeons[9-19]. Based on the data, less experienced surgeons, both from the point of view of duration of experience and percentage of performance, had significantly superior intraobserver agreement to the group of more experienced surgeons. However, the interobserver reliability was not different between these groups.

The mean AOFAS-AHS score obtained was 69 (46-100), and when this functional result was compared to the mean reduction quality scores based on the postoperative X-ray and CT scans, a significant (p=0.043) correlation was observed between the postoperative X-ray-based reduction quality score and the final AOFAS-AHS score, but not between the postoperative CT scan-based reduction quality score and the functional outcome. Table 6 shows the values obtained for each fracture, and figure 1 shows an example of the postoperative CT scan and X-ray of fracture 1, which, despite having an AOFAS-AHS score of 100, had mean score of 4 in the X-ray-based evaluation and a score of 2 in the CT scan-based evaluation.

Table 4. Relationship between experience and mean K value

Examiner experience		K IntraO Sanders -	K IntraO Sanders +	K InterO Sanders -	K InterO Sanders +
Duration of experience	Up to 10 years	0.539	0.511	0.204	0.240
	10 to 20 years	0.474	0.443	0.229	0.244
	p-value	0.029*	0.007*	0.250	0.165
Performance	up to 75%	0.599	0.507	0.178	0.214
	More than 75%	0.559	0.493	0.205	0.225
	p-value	0.021*	0.007*	0.296	0.176

IntraO: intraobserver; InterO: interobserver; Sanders -: Sanders without subclasses; Sanders +: Sanders with subclasses.
Source: Prepared by the author based on the results of the research.

Table 5. K of intraobserver reproducibility and K of interobserver reliability of the Sanders classification found in the literature

Author, year	Examiners	Fractures analyzed	K IntraO Sanders -	K Intra Sanders +	K InterO Sanders -	K InterO Sanders +
Furey 2003[9]	4	30	x	x	0.56	0.48
Bhattacharya, 2005[10]	5	28	0.45	0.42	0.32	0.33
Humphrey, 2005[11]	10*	30†	x	x	0.41	x
Lauder, 2006[12]	8	25	0.77	0.57	0.55	0.48
Schepers, 2009[3]	12	30†	x	x	0.48	0.49
Sayed-Noor, 2011[13]	3	51	x	0.39	x	0.25
Brunner, 2012[14]	4	64	x	0.56(2D)/0.58(3D)	x	0.48(2D)/0.48(3D)
Howells, 2013[15]	3*	40	0.33	0.31	0.4	0.36
Veltmam, 2014[16]	5	38	0.46	0.43	0.22(2D) /0.28(3D)	0.18 (2D)/0.29 (3D)
Piovesana, 2016[17]	4	46	0.66 and 0.44/0.63 and 0.66§	0.63 and 0.33/0.64 and 0.63§	0.60/0.32§	0.53/0.29§
Vosoughi, 2018[18]	2*	100	x	0.91 and 0.75	x	0.48 and 0.58
Misselyn, 2018[19]	24	11	x	x	0.32(2D)/0.51(P3D)	0.29(2D)/0.50(P3D)
Costa, 2019	18	12‡	0.55	0.49	0.2	0.22

IntraO: intraobserver; InterO: interobserver; Sanders -: Sanders without subclasses; Sanders +: Sanders with subclasses; 2D: standard two-dimensional images; 3D: three-dimensional tomographic reconstruction; P3D: three-dimensional printed models.

*: Only experienced examiners. The others were varied.

†: One coronal section made available; ‡: Two coronal sections; §K: of senior residents/K of surgeons

Source: Prepared by the author based on the results of the research.

Table 6. Mean AOFAS-AHS scores and mean reduction quality scores based on postoperative X-ray and CT images

Evaluated fracture	AOFAS-AHS	Reduction quality on CT - mean score	Reduction quality on X-ray - mean score
1	100	2	4
2	55	2	2
3	90	1	2
4	73	1	1
5	62	5	2
6	46	2	4
7	65	3	4
8	59	3	3
9	70	3	3
10	66	4	1
11	57	3	3
12	84	4	5

Source: Prepared by the author based on the results of the research.

Figure 1. Postoperative images of patient 1, who obtained an AOFAS-AHS score of 100, mean score of 4 on the X-ray evaluation, and mean score of 2 on the CT scan evaluation.
Source: Author's personal archive

DISCUSSION

Meta-analyses that compare conservative and surgical treatment of displaced intra-articular fractures show that surgery can reduce the pain associated with walking and allows greater comfort when using shoes. However, these surgical benefits are associated with an increased risk of complications, especially surgical wound infection. Furthermore, no significant differences were observed between patients treated conservatively or surgically in the AOFAS-AHS score, quality of life (SF-36), return to work at the pre-injury level, rate of arthrodesis due to subtalar arthritis, or rate of development of reflex sympathetic dystrophy[20]. These studies also demonstrate the importance of achieving an articular reduction with a step-off <2 mm, restoring Bohler's angle, and correcting the calcaneal shape[5,20-23]. These three postoperative features were cited by most of the examiners when asked about the criteria they evaluated in the postoperative X-ray and CT images (Tables 1 and 2).

It is also important to note that studies show that Sanders type III and IV fractures have a worse prognosis, with higher rates of subtalar arthritis and a need for arthrodesis. Csizy et al.[24] demonstrated that Sanders type IV fractures undergo arthrodesis 5.5 times more often than type II fractures. Sanders et al. concluded that type III fractures, when compared to type II fractures, developed subtalar arthritis 6.5 times more often and had a rate of arthrodesis 4 times higher over a follow-up period of 10 years[4]. Given these findings and the prognostic relationship of the Sanders classification, it is important to understand the factors that may increase its accuracy.

Table 4 compares the studies found in the literature that evaluated the intraobserver reliability and/or interobserver reproducibility of the Sanders classification. We observed a large variation in the intraobserver reliability of the Sanders classification, with results ranging from fair (0.31) to excellent (0.91). In this interpretation, values lower than 0.00 indicate poor agreement; from 0.00 to 0.20, slight; from

0.21 to 0.40, fair; from 0.41 to 0.60, moderate; from 0.61 to 0.80, good or substantial; and from 0.81 to 1.00, excellent agreement finding can be explained, at least in part, by the methodological variation among the studies and the profiles of the examiners, which in some studies were medical students and in others were experienced trauma or foot and ankle surgeons(14).

The data in the literature indicate a slight increase in agreement but are still within the fair to substantial range (0.33 to 0.77) when considering only the number of fragments, without taking into account the position of the fracture lines. However, this analysis should be viewed with caution because the presence of a more medial fracture line in Sanders type III fractures is an indicator of a worse outcome due to the greater technical difficulty of achieving reduction(4). Therefore, the fact that the K value does not increase and that it disregards the position of the fracture lines causes the Sanders classification without subtypes not to have the application benefits demonstrated in the literature.

Combining Sanders type III and IV fractures results in a generic evaluation of injury severity, as these two groups are notable due to a worse prognosis(4,24). Misselyn et al.(19) found an increase in the interobserver K from 0.29 when including the subclasses to 0.32 when both excluding the subclasses and combining Sanders type III and IV fractures in an analyses based on CT with reconstruction. When the same fractures were evaluated based on 3D printed models, the K increased to 0.50 with subclasses, 0.51 without subclasses, and 0.60 with Sanders type III and IV fractures combined. As shown in table 3, we also did not find a change in the interobserver K value when combining type III and type IV fractures.

When excluding foot and ankle surgeons, Roll et al.(25) showed an interobserver agreement of 27% among trauma surgeons. That study, similar to the study of Brunner et al., found a significantly higher agreement among more experienced surgeons(14,25). Lauder et al. found no difference according to the examiners' experience, and in contrast, the study of Piovesana et al. as well as our study found better intraobserver reproducibility among less experienced examiners(12,17).

In the study by Misselyn et al., evaluation based on 3D-CT, with removal of the talus and on 3D printed models of the calcaneus, showed significant improvement in the Sanders classification, increasing the reproducibility in these cases(19). A similar analysis by Veltman et al. and Brunner et al. did not show an improvement in the reproducibility of the Sanders classification with the use of 3D-CT; however, in these two studies, the talus was not removed, hindering the evaluation of the articular surface of the posterior facet of the calcaneus(14,19). Therefore, although we did not find that studies that correlate 3D printed models with removal of the talus had better functional or clinical outcomes, we argue that this technique should be adopted as a routine in calcaneal fractures because it provides more accurate anatomical information and a significant increase in the reproducibility of the Sanders classification. Regarding 3D printed models of the calcaneus, some hospitals already use this method as a routine in displaced intra-articular fractures for patient guidance and pre- and perioperative planning to help understand the fracture(26). Thus, further studies are needed to confirm its positive influence on the final outcome of calcaneal fracture treatment, but we believe that 3D printed models will be an increasingly widespread method, especially after a reduction in the costs of 3D fabrication.

Lastly, among the analyses performed, a significant correlation was found between the reduction quality assessed by X-ray and the functional outcome measured by the AOFAS-AHS score. However, this did not occur when the examiners judged the two coronal CT scans. Sanders et al. and Buckley et al. mentioned that one of the factors that caused non-agreement between anatomical reduction and a good outcome is injury to the cartilage in the posterior facet at the time of fracture or necrosis secondary to the trauma(4,23). Reconstructing the calcaneal shape should be a primary objective, especially by achieving correct Bohler's and Gissane's angles and preventing the talus from collapsing into the calcaneus and rotating in dorsiflexion, which would cause loss of ankle motion, pain, and limitation of activities(27). The width should also be reestablished, avoiding projections on the lateral wall to prevent affecting the peroneal tendons or fibula(27).

CONCLUSION

The intraobserver reproducibility of the Sanders classification was inversely influenced by the surgeon's duration of experience and the percentage of foot and ankle surgery performed.

The intraobserver K values without considering subclasses and when combining type III and IV fractures were moderate and were not more reproducible than the original classification.

Regarding interobserver reproducibility, our findings ranged between slight and fair (0.20 to 0.22), and it is possible that including the option "inadequate image" with the Sanders classification options contributed to a reduction in the K value.

Lastly, we confirmed the correlation between postoperative radiological assessment and the AOFAS-AHS score, but we did not observe a relationship when only the coronal CT scan at the level of the sustentaculum of the talus was evaluated.

Authors' contributions: Each author contributed individually and significantly to the development of this article: LHGMC *(https://orcid.org/0000-0002-6679-3723) conceived and planned the activities that led to the study, wrote the article, participated in the review process, approved the final version; TAAS*(https://orcid.org/0000-0003-2333-2334) conceived and planned the activities that led to the study, performed the surgeries, data collection, interpreted the results of the study, participated in the review process, approved the final version; WAB *(https://orcid.org/0000-0001-6373-1247) interpreted the results of the study, approved the final version; DSB *(https://orcid.org/0000-0001-5404-2132) conceived and planned the activities that led to the study, performed the surgeries, participated in the review process, approved the final version. *ORCID (Open Researcher and Contributor ID).

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