

Original Article

Primary subtalar arthrodesis in the treatment of comminuted calcaneal fractures: a functional and quality of life analysis

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Abstract

Objective: To survey literature findings on primary arthrodesis in Sanders type III and IV fractures and analyze functional and quality of life outcomes in patients submitted to this initial surgical procedure.

Methods: This study described the profile of 12 patients diagnosed with severe comminuted intra-articular calcaneal fractures of Sanders type III and IV operated by a foot and ankle team. Patients attended from January 2016 to August 2021 with pre-/postoperative follow-up and application of the Orthopedic Foot and Ankle Score (AOFAS) questionnaire and Short Form Health Survey 36 (SF-36) quality of life questionnaire, along with clinical evaluation, were included. Data search was performed using the following online databases: PUBMED, MEDLINE, LILACS, and SCIENCE.

Results: Most patients had a good range of motion, a mean AOFAS score of 81.71 points, and high mean scores in the domains physical functioning (84.44 points), role-physical (5.55 points), bodily pain (23 points), and general health (96.11 points) according to the SF-36 questionnaire. In general, there was bone consolidation after primary arthrodesis of the subtalar joint, and the functional status of patients was satisfactory.

Conclusion: Primary arthrodesis is a relevant choice in fractures with more than three fragments, with a better postoperative outcome, including pain and maintenance of the hindfoot axis. Larger studies should be performed to assess more results of primary arthrodesis as a first treatment option for Sanders type III and IV fractures.

Level of Evidence IV; Therapeutic Study; Case Series.

Keywords: Calcaneus; Fractures, bone; Orthopedic procedures/methods; Quality of life; Surveys and questionnaires.

Introduction

Calcaneal fractures are the most prevalent foot fracture, accounting for 65% of tarsal bone fractures and 2% of all body fractures^(1,2). The treatment of comminuted intra-articular calcaneal fractures is controversial in some randomized studies published in the literature; however, both the surgical and the conservative treatments undoubtedly present pros and cons, as well as relevant risk factors for unfavorable evolution⁽³⁾. Patients with this type of injury may develop painful post-traumatic subtalar arthritis, requiring fusion regardless of the initial choice of treatment⁽¹⁾.

Calcaneal fractures result from low- or high-energy injuries, and bilateral involvement is rare in less than 10% of cases⁽⁴⁾. Regarding the mechanism of injury, the main contributing force of the mechanism of fracture in more than 60% of cases is the axial load, often due to a fall from height⁽⁴⁾. The excessive axial load transferred to the Gissane's angle determines a primary fracture line that affects the neutral triangle (region with sparse trabeculae under the subtalar bone)⁽⁴⁾.

The population segment most affected by this condition is working-age adult men. Almost 75% of cases are intra-articular fractures and commonly evolve with a poor functional

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outcome, including not being able to return to work with full working capability, which generates clinical and socioeconomic effects⁽⁴⁾.

In 1952, Essex-Lopresti⁽⁵⁾ described a classification system that divided calcaneal fractures into two types: intra-articular and extra-articular types, also known as joint depression fractures and tongue fractures. This classification is based only on plain radiograph, specifically lateral view.

The Sanders classification for calcaneal fractures is based on coronal computerized tomography sections. It considers the displacement and the number and location of fracture lines below the surface of the posterior facet of the talus, which is divided into three columns (the lateral, central, and medial columns) by three lines (A, B, and C) from the lateral to the medial column^(4,6). This classification can be briefly divided into:⁽⁶⁾

- Type 1: Fractures with less than 2mm of displacement;
- Type 2: Fractures into two parts with one fracture line, divided into three subtypes based on the fracture line location: lateral (IIA), central (IIB), or medial (IIC);
- Type 3: Fractures into three parts with two fracture lines, divided into the following subtypes: IIIAB (one lateral and one central to the posterior facet and subtalar joint); III-AC (one lateral and one medial to the posterior facet and subtalar joint); IIIBC (one central and one medial to the posterior facet and subtalar joint); and
- Type 4: Comminuted fractures⁽⁶⁾.

Surgical treatment of calcaneal fractures was first described in 1948 by Palmer apud Wei et al.⁽⁶⁾ and, later, by Essex-Lopresti⁽⁵⁾, in 1952, aiming to reduce the subtalar joint, as incomplete reduction causes unsatisfactory functional outcomes and an 1mm deviation was sufficient to alter the posterior facet and cause gait disturbances.

Though conservative treatment eliminates the risks associated with the surgical procedure, there is often a symptomatic malunion when no attempt is made to restore the height, hindfoot alignment, and talus inclination based on the subtalar and calcaneocuboid joints⁽¹⁾.

Sanders and other authors observed that surgical treatment could relieve the pain, reestablish a plantigrade foot, and improve patient function⁽¹⁾. In comminuted intra-articular fractures of the calcaneus into three or more parts (Sanders type III and IV), it is more difficult to restore the joint anatomy and congruency, the calcaneal height, and the talus-calcaneus relationship; thus, studies evidenced that primary subtalar arthrodesis is beneficial as an initial surgical intervention and as a definitive treatment for these fracture types^(1,3).

Methods

This study was approved by the Research Ethics Committee. All participants signed an informed consent form.

This study presents a retrospective, descriptive analysis of 12 patients with calcaneal fractures operated at an emergency tertiary public hospital with residency training in orthopedics

and traumatology. These patients were attended from January 2016 to July 2021 and submitted to primary arthrodesis of the subtalar joint after receiving an initial diagnosis of Sanders type III or IV intra-articular calcaneal fracture, not requiring bone graft. All patients were operated on by the same ankle and foot surgical team, observing their clinical and soft tissue conditions for osteosynthesis, with implants available in the public health system.

The following descriptive variables were analyzed: age, sex, involved side, accident type, number of surgeries, consolidation time, and mean follow-up period. The parameters calcaneal axis and measure of Böhler and Gissane's angles after surgery were also analyzed.

All patients were evaluated, and radiographs were performed in all outpatient follow-up visits, at least 2, 4, 8, 12 weeks, 6 months, and 1 year after surgery. This study describes the mean score for each follow-up visit of Orthopedic Foot and Ankle Score (AOFAS) and Short Form Health Survey 36 (SF-36) questionnaires.

The standardization of the clinical and functional outcome analyses is represented using the AOFAS Ankle-Hindfoot Scale and SF-36 quality of life questionnaires.

The AOFAS Ankle-Hindfoot Scale is composed of nine items distributed into three categories: pain (40 points), functional aspects (50 points), and alignment (10 points), totaling 100 points. The score is found by adding points, where 80-100 is excellent; 60-80, good; 40-60, fair; and >40, poor⁽⁷⁾.

The SF-36 questionnaire is an instrument for quality-of-life and is composed of 36 items distributed into eight domains: physical functioning, role-physical, bodily pain, general health, vitality, social functioning, role-emotional, and mental health. Scores range from 0 to 100, from the worst to the best health status⁽⁸⁾.

Surgical Technique

All patients were operated in full lateral decubitus position with an elastic tourniquet. Extended lateral approach was performed in 'L' in a single plane, with direct subperiosteal dissection and no skin delamination to avoid skin necrosis and suffering for an extended approach. Dissection of the plane close to the bone at the lateral calcaneal wall must be performed using a sharp dissector, as the lateral wall comminution may hinder such dissection close to the cortical surface. Dislocation of fibular tendons must be performed along with this skin flap, and spacing must be performed with due care. Anchoring with 1.5mm Kirschner wire in the fibula and talus is used as fixed space maintainer, avoiding soft tissue distancing and traction and minimizing the risk of injuries to the skin, leaving the hands of a surgical assistant free.

Upon the fracture realignment, the first parameter to be considered is the depressed posterior facet that needs to be elevated using the talus facet as a control to reestablish the calcaneal height and width. Keeping the parallelism between the posterior calcaneal facet and the talus helps restoring these height and pitch parameters, maintaining such reduc-

tion with Kirschner wires. Then, the exeresis of subtalar joint surface cartilages is performed, and the arthrodesis is fixed with radioscopic aid using two or three 7.0mm cannulated screws inserted from the plantar to the dorsal aspect through the calcaneus to the talus. In some cases, a calcaneal plate was also used at the lateral wall-a decision made intraoperatively when there is an important lateral comminution and a central void with no bone support, causing a great lateral instability (Figure 1). The calcaneal plate was fixed using 3.5mm cortical screws in the posterior and anterior portions with no pattern, but according to the fracture personality, keeping the calcaneus positioning with a 0-5 valgus degree. In cases of major lateral comminution, the supporting plate reduces the calcaneus width and adds stability. In all cases, a suction drain was placed, and a two-layer closure was performed using 2-0 absorbable sutures subcutaneously and 4-0 nylon sutures on the skin layer. The drain was removed on the second postoperative day, always immobilizing the limb in plaster cast. All patients initiated the ankle joint early mobilization with no weight-bearing for eight weeks. Full weight-bearing was allowed when subtalar joint fusion and consolidation were evidenced, on average, 10 to 12 weeks postoperatively (Figure 2).

Results

From January 2016 to July 2021, 12 patients were submitted to surgery for calcaneal fractures. All patients were followed up at 2, 4, 8, 12 weeks, 6 months, and 1 year postoperatively.

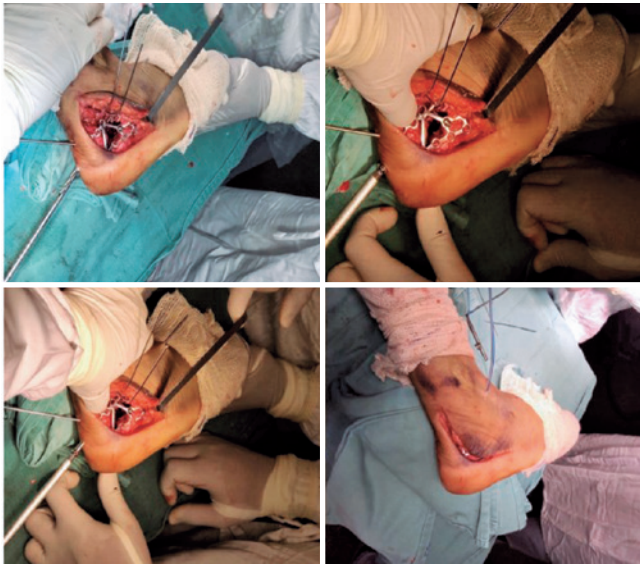


Figure 1. Lateral approach in 'L'; Kirschner wires keeping the spacing between soft tissues and aiding in the reduction; and calcaneal fracture fixation with lateral support plate and cannulated screws.

Source: Author's personal archive.

Patients were clinically evaluated using the AOFAS scale and SF-36 questionnaire. During the follow-up period, comparative radiographs were performed to assess the joint fusion, bone consolidation, and possible signs of osteoarthritis in adjacent joints. The operated hindfeet presented neutral or valgus alignment, and the calcaneal axis was fully restored in all cases. All patients ambulated without crutches.

Subtalar joint range of motion in operated feet was 0° in all patients, and ankle instability was not observed. Most patients did not report pain; only one patient reported pain after weight-bearing was allowed.

Male sex was the most prevalent (66.7%), the right side was the most involved (58.3%), and the mean age was 42.75 years (range 23 to 61 years), with a median of 44.5 years and a standard deviation of 13.15727. Fractures were caused by high-energy injuries-nine by falls from height and three during motorcycle accidents-, and all of them were closed fractures.

All fractures were firstly evaluated in the emergency care setting, and below-knee plaster cast immobilization was performed. Surgeries were performed as soon as an edema reduction and improvement in the soft tissue condition were observed, about 15 days from fracture. No skin necrosis was

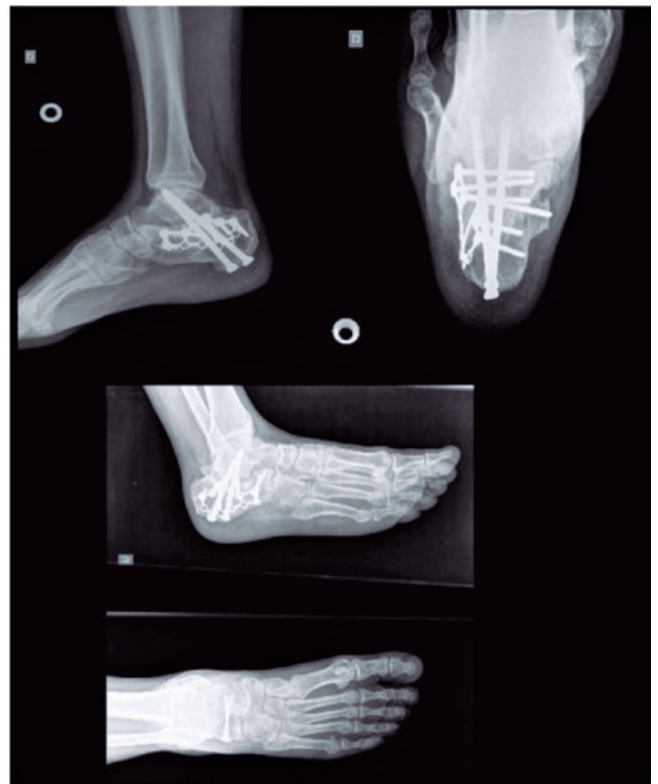


Figure 2. Follow-up radiograph of a 47-year-old patient at 90 days postoperatively showing complete subtalar joint fusion after arthrodesis with plate and cannulated screws.

Source: Author's personal archive.

seen in operated patients; however, there was a skin infection in the cannulated screw route, with synthesis material removal after bone consolidation.

Most patients presented a good range of motion, obtaining a mean AOFAS score of 82.25 points (out of 100 possible points), with a median of 80.5 points and a standard deviation of 5.41, a minimum value of 76, and a maximum of 92 points. The AOFAS scores are detailed in table 1. As for the SF-36 questionnaire, high means were observed in physical functioning, role-physical, bodily pain, and general health, with 84.16, 93.75, 78.5, and 90.58 points, respectively. It should be stressed that, in the role-physical or bodily pain scores, the closest the score to the 100 points possible, the better the patient outcome, the lesser the incapacity, or the lesser the pain during postoperative follow-up. Data related to the SF-36 questionnaire are shown in table 2.

Table 1. AOFAS questionnaire result per patient

Patient	AOFAS Score
N. 1	76
N. 2	89
N. 3	81
N. 4	84
N. 5	80
N. 6	92
N. 7	79
N. 8	78
N. 9	76
N. 10	78
N. 11	88
N. 12	86

Table 2. SF-36 quality of life questionnaire result

Patient	Evaluated Aspects			
	Physical Functioning	Role-Physical	Bodily Pain	General Pain
N. 1	90	100	69	97
N. 2	90	100	79	92
N. 3	70	75	90	100
N. 4	70	75	58	100
N. 5	95	100	69	82
N. 6	90	100	90	100
N. 7	70	100	90	100
N. 8	90	100	79	97
N. 9	95	100	69	97
N. 10	65	75	62	62
N. 11	90	100	95	77
N. 12	95	100	92	83

Description 1: 0 = worst condition and 100 = best condition
Source: Microsoft Excel version 16.54, 2021.

All parameters considered in the study are detailed in table 3.

Discussion

Intra-articular fractures with acute calcaneal comminution cause a loss in the hindfoot height, directly hindering the force vectors of a stable, functional gait and quality of life aspects, such as wearing shoes⁽¹⁾.

Many authors agree that treating Sanders type III and IV calcaneal fractures is challenging and that the calcaneal joint surface is often extensively damaged^(7,8).

Surgical treatment is indicated in intra-articular calcaneal fractures with displacement, especially when the posterior facet is affected, aiming to restore the anatomy of joint surfaces and reestablishing the joint function^(9,10).

General analysis of Liu et al.⁽³⁾ showed that surgery is still required in case of intra-articular calcaneal fractures with displacement (RR 4.40, 95% CI [2.62-7.39], p<0.001) to restore the Böhler's angle and the calcaneus height and width, enable patient to return to their former professional activities with a better functionality, and restore the anatomical structures of the calcaneus⁽²⁾.

According to Sanders et al.⁽¹¹⁾ and Wei et al.⁽⁶⁾, about 70% of Sanders type IV comminuted calcaneal fractures evolve to post-traumatic arthritis, while 73% of fractures evolve to secondary subtalar arthrodesis. Several studies corroborate the idea that cases with major depression of the Böhler's angle are at high risk of developing painful post-traumatic arthrosis, despite all operative fixation and anatomical joint reduction techniques available, ultimately evolving to subtalar arthrodesis^(9,10,12-15). Recognizing this fact indicates an increase in the incidence of primary subtalar arthrodesis^(12,16), in addition to other functional and radiographic data demonstrating that patients who underwent primary arthrodesis obtained more favorable functional outcomes than those who underwent primary reconstruction with residual subtalar motion^(12,15,17,18). Likewise, in this study, which involved 12 patients, the mean AOFAS score was 82.25 points, and high means were observed in the SF-36 domains of physical functioning (84.16), role-physical (93.75), bodily pain (78.5), and general health (90.58). As the closest to 100 points, the better the outcome, all patients achieved little limitation and pain, a better health condition, and better physical functioning. This study's data corroborate the literature, reiterating that primary subtalar arthrodesis may be considered in patients with Sanders type III and IV intra-articular fractures with important displacement^(8,17,18).

Buckley et al.⁽²⁾ gathered data from 14 patients with comminuted intra-articular fractures of the calcaneus treated with primary subtalar arthrodesis and followed up for 26 months postoperatively. The mean AOFAS score was 72.4 points, and the authors concluded that primary subtalar fusion is the treatment of choice for Sanders type IV fractures and that primary arthrodesis produces better clinical outcomes than secondary arthrodesis⁽²⁾.

Table 3. Statistical data, such as fracture time until surgery, and post-arthrodesis correction parameters, such as valgus, Böhler's angle, and Gissane's angle

Patient	Sex	Laterality	Age	Fracture Time	Sanders Type	Valgus	Böhler's Angle	Gissane's Angle	Fixation Type
1	Male	Right	38	15	III	0	36	120	Plate and cannulated screws
2	Male	Left	47	13	IV	2	32	130	Plate and cannulated screws
3	Female	Left	44	10	IV	3	41	122	Plate and cannulated screws
4	Male	Right	52	8	III	5	31	126	Cannulated screws
5	Male	Right	57	9	II	0	27	136	Cannulated screws
6	Male	Left	61	11	V	1	28	127	Cannulated screws
7	Male	Right	35	9	V	0	25	135	Plate and cannulated screws
8	Female	Right	30	10	II	4	30	124	Plate and cannulated screws
9	Male	Left	45	12	IV	3	29	140	Plate and cannulated screws
10	Male	Right	58	13	II	2	23	137	Cannulated screws
11	Female	Right	23	11	IV	0	26	133	Cannulated screws
12	Female	Left	23	14	IV	5	34	128	Cannulated screws

Holm et al.⁽¹²⁾ conducted a comparative study involving 17 patients with extremely comminuted calcaneal fractures submitted to primary arthrodesis to assess which radiographic parameters were predictive of functional outcome. Patients were operated through an extended incision made over the sinus tarsi instead of through an extended lateral approach to reduce soft tissue damage. The mean AOFAS score was 78.4 (range 56 to 92), with a mean follow-up duration of 34 months. The authors considered that the best functional outcomes were achieved in younger patients ($p=0.028$), with a greater percentage of Böhler's angle and talocalcaneal restoration ($p=0.038$ and $p=0.049$, respectively)⁽¹²⁾. In this study, the laterality ($p=0.355$), sex ($p=0.371$), age ($p=0.313$), fracture time ($p=0.374$), Sanders classification ($p=0.355$), and post-arthrodesis valgus ($p=0.410$) parameters were not statistically significant as predictive of the AOFAS functional score. It should be stressed that the essential Böhler and Gissane's angles and the calcaneus height were restored with a good correction, and all patients presented bone consolidation, corroborating the findings described in the literature, which


the bone fusion rate is 65-100%⁽¹⁹⁾ and the pseudoarthrosis rate is 0-24%⁽²⁰⁾ after primary arthrodesis.

Conclusion

Primary arthrodesis of the subtalar joint is a treatment option for patients with Sanders type III and IV calcaneal fractures, promoting good outcomes by observing the injury profile. In addition, it is widely recognized as a good method to be considered during surgical procedures.

In care settings facing difficulties performing secondary arthrodesis, such as lack of beds and other inputs, primary subtalar arthrodesis may be considered the main treatment for Sanders type III and IV calcaneal fractures, as already described in current literature.

Larger studies should be performed to evaluate more results of primary arthrodesis as the treatment of choice for Sanders type III and IV fractures, disregarding the short sample used in this study.

Author's contributions: Each author contributed individually and significantly to the development of this article: ARNL *(orcid.org/0000-0002-0715-6417) Conceived and planned the activities that led to the study, interpreted the results of the study, participated in the review process, performed the surgeries, data collection, statistical analysis, bibliographic review, survey of the medical records, formatting of the article, clinical examination, approved the final version; JSM *(orcid.org/0000-0003-4742-1905) Conceived and planned the activities that led to the study, interpreted the results of the study, participated in the review process, performed the surgeries, data collection, statistical analysis, bibliographic review, survey of the medical records, formatting of the article, clinical examination, approved the final version; BAMS *(orcid.org/0000-0002-3008-460X) Conceived and planned the activities that led to the study, bibliographic review, survey of the medical records, formatting of the article, approved the final version; AFMJ *(orcid.org/0000-0002-6430-8974) Conceived and planned the activities that led to the study, interpreted the results of the study, participated in the review process, performed the surgeries, data collection, formatting of the article, clinical examination, approved the final version; MHMS *(orcid.org/0000-0001-8316-5131) Conceived and planned the activities that led to the study, interpreted the results of the study, participated in the review process, performed the surgeries, data collection, statistical analysis, bibliographic review, survey of the medical records, formatting of the article, clinical examination, approved the final version; WFM *(orcid.org/0000-0003-0845-4130) Conceived and planned the activities that led to the study, interpreted the results of the study, participated in the review process, performed the surgeries, data collection, statistical analysis, bibliographic review, survey of the medical records, formatting of the article, clinical examination, approved the final version; DPL *(orcid.org/0000-0001-8000-7234) Conceived and planned the activities that led to the study, interpreted the results of the study, data collection; ACMO *(orcid.org/0000-0001-8516-444X) Performed the surgeries, data collection, statistical analysis, bibliographic review, survey of the medical records, formatting of the article, clinical examination, approved the final version; GFR *(orcid.org/0000-0003-4979-7826) Data collection, statistical analysis, bibliographic review, survey of the medical records, formatting of the article, approved the final version; RVR *(orcid.org/0000-0003-2841-7003) Data collection, statistical analysis, bibliographic review, survey of the medical records, formatting of the article, approved the final version. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID) 

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