Medical Journal of Bakırköy

Med J Bakirkoy 2025;21(3):316-322
DOI: 10.4274/BMJ.galenos.2025.2025.4-4

Research

Percutan Crossed Dual Planar Pin Fixation Technique Provides Satisfactory Radiological and Clinical Results in Intra-articular Calcaneus Fractures with Low Complication Rates

Perkütan Çapraz Çift Planar Pin Fiksasyon Tekniği, Düşük Komplikasyon Oranlarıyla Eklem İçi Kalkaneus Kırıklarında Tatmin Edici Radyolojik ve Klinik Sonuçlar Sağlar

Berhan Bayram[1], Mustafa Gökhan Bilgili[2]

[1]Acıbadem Altunizade Hospital, Clinic of Orthopedic Surgery and Sport Medicine, İstanbul, Türkiye
[2]University of Health Sciences Türkiye, Bakırköy Dr. Sadi Konuk Training and Research Hospital, Clinic of Orthopedics and Traumatology, İstanbul, Türkiye

ABSTRACT

Objective: This study aimed to evaluate the clinical and radiological results of crossed double-plane pin fixation of intra-articular calcaneus fractures based on the Sanders classification.

Methods: The study was designed retrospectively. Patients who were operated on using the crossed double-plane pin fixation technique between 2013 and 2017 were included in the study. Patients under the age of 18 who had previously undergone surgery around the foot/ankle with extra-articular fractures with fractures on the ipsilateral or contralateral lower extremity were excluded from the study. All patients were operated on by a single surgeon in a single clinic. All patients were categorized according to the Sanders classification, with pre-operative computed tomography. The Böhler angle was used for radiological evaluation, and the American Orthopaedic Foot and Ankle Society score was used for clinical evaluation.

Results: After applying the inclusion and exclusion criteria, a total of 52 fractures of 46 patients were included in the study. Thirty-six (78.3%) of the patients were male and 10 (21.7%) were female. Twenty-one patients had right-sided fractures (45.7%), nineteen patients had left-sided fractures (41.3%), and six patients had bilateral fractures (13%). The mean patient age at the time of treatment was 39.6 years (15-64 years). Fractures were classified according to the Sanders classification system. According to this classification, eight of the fractures were type 2 (15.4%), thirty-five were type 3 (67.3%), and nine were type 4 (17.3%). Of the forty-five calcaneus fractures with abnormal preoperative Böhler values, thirty-three (73%) had normal Böhler values in postoperative control measurements. There was a statistically significant difference between preoperative and postoperative measurements in terms of Böhler distributions ($p<0.05$). While the baseline rate was low in the preoperative measurement, it was higher in the postoperative measurement. In addition, a statistically significant difference was found in the number of individuals returning to normal as per Sanders grouping (Fisher's exact $p<0.05$). The rate of those with Sanders 3 was found to be higher compared to others.

Conclusion: Double pin fixation technique in intra-articular calcaneus fractures provides satisfactory radiological and clinical results with low complication rates.

Keywords: Calcaneus fracture, percutaneous, cross, pin, fixation

Address for Correspondence: Berhan Bayram MD, Acıbadem Altunizade Hospital, Clinic of Orthopedic Surgery and Sport Medicine, İstanbul, Türkiye
E-mail: dr.berhanbayram@gmail.com **ORCID ID:** orcid.org/0000-0003-3777-5611

Cite as: Bayram B, Bilgili MG. Percutan crossed dual planar pin fixation technique provides satisfactory radiological and clinical results in intra-articular calcaneus fractures with low complication rates. Med J Bakirkoy. 2025;21(3):316-322

Received: 08.05.2025
Accepted: 31.05.2025
Publication Date: 03.09.2025

ÖZ

Amaç: Bu çalışma ile intra-artikuler kalkaneus kırıkların çapraz çift planlı pin fiksasyonun klinik ve radyolojik sonuçlarının Sanders sınıflandırması baz alınarak değerlendirilmesi amaçlanmıştır.

Gereç ve Yöntem: Çalışma retrospektif olarak dizayn edilmiştir. 2013-2017 yılları arasında çapraz çift planlı pin fiksasyonu tekniği kullanılarak opere edilen hastalar çalışmaya dahil edildi. On sekiz yaşın altındaki hastalar, daha önce ayak/ayak bileği çevresinden cerrahi geçiren hastalar, ekstra artiküler kırığı olan hastalar, aynı tarafta veya karşı taraf alt ekstremitesinde kırığı olan hastalar çalışma dışında bırakıldı. Hastaların tamamı tek bir klinikte tek bir cerrah tarafından opere edildi. Hastaların tamamı pre-operatif çekilen bilgisayarlı tomografi ile Sanders sınıflamasına göre kategorize edildi. Radyolojik değerlendirme için Böhler açısı, klinik değerlendirme içinse Amerikan Ortopedi Ayak ve Ayak Bileği Derneği skoru kullanıldı.

Bulgular: Dahil edilme ve dışlanma kriterlerinden sonra çalışmaya toplamda 46 hastanın 52 kırığı dahil edildi. Hastaların 36'sı (%78,3) erkek, 10'u (%21,7) kadındı. Yirmi bir hastada sağ taraf (%45,7), 19 hastada sol taraf (%41,3), altı hastada ise her iki tarafta (%13) kırık saptandı. Tedavi anında ortalama hasta yaşı 39,6 (15-64) idi. Kırıklar Sanders sınıflandırma sistemine göre sınıflandırıldı. Bu sınıflandırmaya göre kırıkların 8'i tip 2 (%15,4), 35'i tip 3 (%67,3), 9 tanesi de tip 4 (% 17,3) olarak saptandı. Preop Böhler değeri normal olmayan 45 kalkaneus kırığının, postop kontrol ölçümlerinde 33 tanesinin (%73) Böhler değerlerinin normale geldiği görüldü. Preop ve postop ölçümleri arasında Böhler dağılımları açısından istatistiksel anlamlı farklılık saptandı ($p<0,05$). Önce ölçümünde normal oranı düşükken sonra ölçümünde daha yüksek olduğu görüldü. Ayrıca Sanders gruplamasına göre normale geçenler açısından istatistiksel anlamlı farklılık saptandı (Fisher'ın kesin testi $p<0,05$). Sanders 3 olanların oranı daha yüksek bulunmuştur.

Sonuç: İntra-artiküler kalkaneus kırıklarında çift pin fiksasyon tekniği düşük komplikasyon oranları ile tatmin edici radyolojik ve klinik sonuçlar sağlar.

Anahtar Kelimeler: Kalkaneus kırığı, perkütan, çapraz, pin, fiksasyon

INTRODUCTION

The calcaneus is the most commonly fractured tarsal bone, representing approximately 60% of foot fractures and 1-2% of all fractures (1). Calcaneal fractures are associated with significant morbidity and a high rate of complications (2,3). Notably, over 70% of these fractures are intra-articular, affecting the subtalar joint (4). Displaced intra-articular calcaneal fractures (DIACF) can result in various functional issues, including hindfoot deformities, persistent pain, and chronic stiffness (5). When treated conservatively, DIACF is linked to poor clinical outcomes due to the development of subtalar arthritis and disruption of foot morphology (6).

The management of intra-articular calcaneal fractures is complex and presents numerous challenges. The primary objectives of treatment are to restore the calcaneal height and length to their pre-injury state and to reconstruct the posterior joint surface (7). Although the fundamental goals of treatment modalities are consistent, the optimal approach for managing intra-articular calcaneal fractures remains a topic of debate (8). These fractures are frequently addressed using open reduction and internal fixation (ORIF) via an extensile lateral approach. However, this method carries a considerable risk of wound complications and sural nerve injury (9,10). As a result, there has been a growing preference for less invasive techniques in the treatment of intra-articular calcaneal fractures. Among these approaches, percutaneous screw fixation has demonstrated the ability to reduce wound complications while achieving satisfactory reduction (11,12). Additionally, percutaneous fixation with K-wires offers benefits such as lower implant costs and shorter surgical times. Literature suggests that it can yield outcomes comparable to traditional ORIF (13,14). These encouraging findings have contributed to the increasing adoption of minimally invasive techniques in recent years. Nonetheless, there is a notable lack of comprehensive studies to identify which patient populations are most suitable for these methods.

In this study, we aimed to classify intra-articular calcaneal fractures treated with cross dual-planar pin fixation according to the Sanders classification (15) and to assess the impact of this technique on both radiological and clinical outcomes. By doing so, we sought to enhance the existing literature on patient selection for this approach. We hypothesized that patients with Sanders type 2 and type 3 fractures would experience better outcomes compared to those with type 4 fractures.

METHODS

Demographic Characteristics and Preoperative Plan

The study was designed as a retrospective study. Data collection began after approval from the Clinical Research Ethics Committee of the University of Health Sciences Türkiye, Bakırköy Dr. Sadi Konuk Training and Research Hospital (approval no: 2018-03-23, date: 12.02.2018). Patients who underwent surgery for intra-articular calcaneal fractures at our hospital between 2012 and 2017 were retrospectively reviewed. Among these, only patients operated on using the cross dual-planar pinning technique were included in the study. Exclusion criteria included patients under the age of 18, those with open calcaneal

fractures, extra-articular calcaneal fractures, ipsilateral or contralateral lower extremity fractures, pathological fractures, a history of prior foot or ankle surgery, a diagnosis of rheumatologic disease, or neurovascular deficits in the affected extremity. Patients presenting to the emergency department due to trauma underwent anteroposterior (AP), lateral, and axial radiographs of the ankle, in cases where a calcaneal fracture was suspected. For patients diagnosed with a calcaneal fracture based on radiographic imaging and clinical examination, a foot and ankle computed tomography (CT) scan was performed to classify the fracture. The Sanders classification system was used for all patients. The classification of CT scans for all cases was performed by the primary author of this study.

Surgical Technique

All surgical procedures were performed at a single center by the same surgeon. General or spinal anesthesia was administered to all patients for the surgical intervention. A tourniquet was not applied during the procedures. The surgeries were conducted with the patients the prone position. This surgical technique involves the use of two crossed Schanz screws, positioned posteromedially and posterolaterally.

Initially, a screw was inserted from the posteromedial aspect in a manner parallel to the collapsed joint fragment. This Schanz screw was directed to pass just beneath the fragment, requiring elevation from the tuber calcanei. The entry point and direction of the Schanz screw were determined using C-arm fluoroscopy. Once the screw was positioned appropriately, it was manipulated medially to laterally to correct the varus alignment. Simultaneously, the screw was advanced in a cranial-to-caudal direction to facilitate the reduction of the collapsed joint fragment. If adequate fracture reduction was achieved, the Schanz screw was advanced to the most distal part of the calcaneus without penetrating the calcaneocuboid joint. Following the placement of the first screw, the entry point for the second screw was also determined under C-arm fluoroscopic guidance. The posterolateral screw was directed from the tuber calcanei, passing beneath the residual impacted fragment and parallel to the collapsed joint fragment. At this stage, multiple radiographic views were required to confirm the correct direction of the screw. Unlike the first screw, the second screw was manipulated solely for joint fragment elevation before being advanced to the most distal aspect of the calcaneus. After the percutaneous placement of the screws, reduction was assessed using C-arm fluoroscopy. Finally, the screw entry points were closed with absorbable sutures, and all patients were immobilized in a long leg cast after forefoot manipulation. The dual shanz fixation technique was applied as described by Duramaz et al. (16). All patients received antibiotic prophylaxis during anesthesia induction, followed by two additional postoperative doses. Low-molecular-weight heparin was administered to all patients as prophylaxis against thromboembolic disease.

Postoperative Follow-up

Following discharge, all patients were scheduled for follow-up visits every two weeks during the first month, monthly thereafter, and annually after six months from the discharge, if no additional complaints were reported. At each follow-up, AP, lateral, and axial radiographs of the ankle were obtained for all patients. CT was performed only once, on the first postoperative day. Böhler's angle was measured from preoperative and postoperative day 1 radiographs for all patients. The measurements were independently conducted by two different orthopedic specialists (BB and MGB), and the mean values of both measurements were used for statistical analysis. For clinical evaluation, the American Orthopaedic Foot and Ankle Society (AOFAS) score (17) was assessed at the final follow-up. In cases of bilateral fractures, a separate AOFAS score was calculated for each foot. Pre-operative, intra-operative, and post-operative radiographs of one of the patients included in the study are shown in Figure 1.

Statistical Analysis

Descriptive statistics were used to describe continuous variables. The relationship between two independent categorical variables was analyzed using Fisher's exact test, while the relationship between two dependent categorical variables was assessed using the McNemar test. The level of statistical significance was set at 0.05. All statistical analyses were performed using MedCalc Statistical Software version 12.7.7 (MedCalc Software Ltd., Ostend, Belgium).

RESULTS

A total of 52 calcaneal fractures in 46 patients were included in the study. The majority of the patients were male (78.3%). The fractures were located on the right side in 21 patients (45.7%), on the left side in 19 patients (41.3%), and on the bilateral side in 6 patients (13%). The mean age of the patients was 39.6 years (range: 15-64 years).

Preoperative CT scans were used to classify the fractures according to the Sanders classification. Based on this classification, 8 fractures (15.4%) were categorized as Sanders type 2, 35 fractures (67.3%) as Sanders type 3, and 9 fractures (17.3%) as Sanders type 4. The distribution of patients according to sex, laterality, and Sanders classification is presented in Table 1.

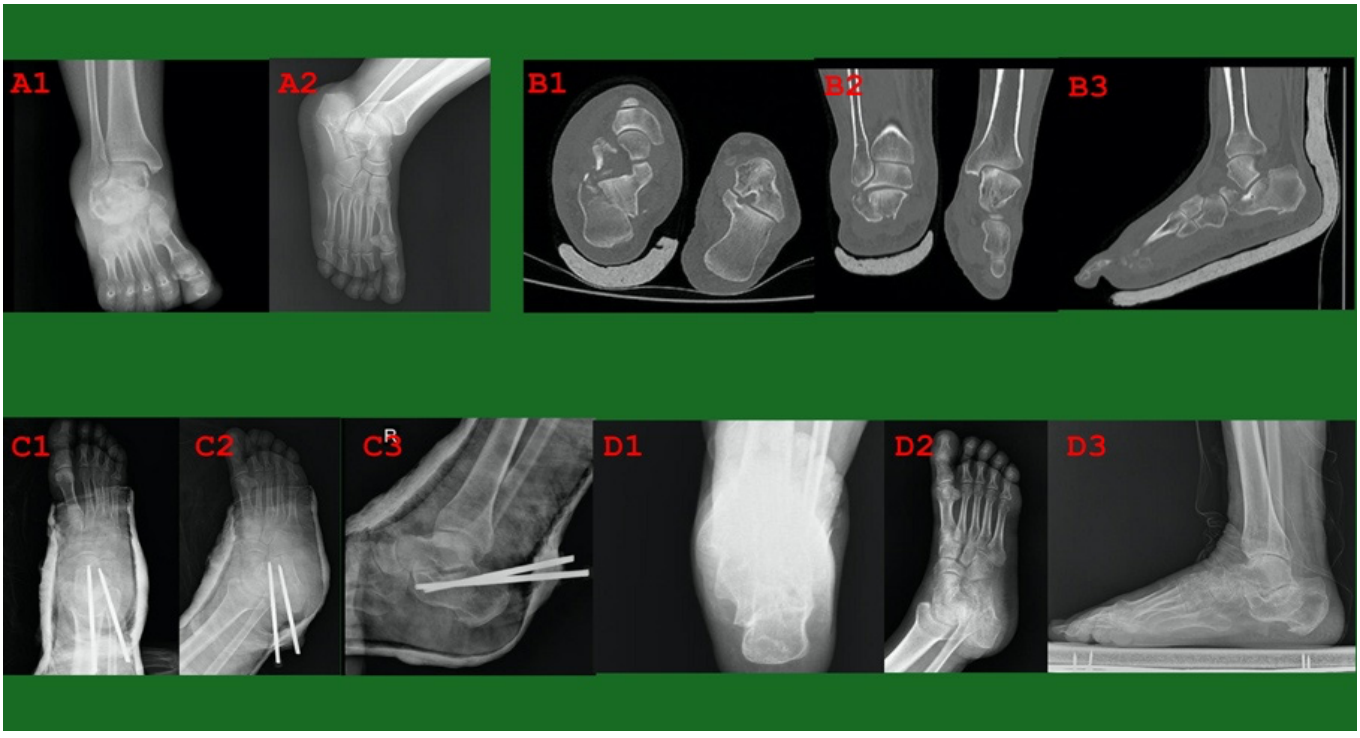

Figure 1. Fifty-five-year-old male admitted after falling from a height. **A1.** Pre-operative AP radiographs showing comminuted intra-articular calcaneus fracture. **A2.** Pre-operative lateral radiographs showing comminuted intra-articular calcaneus fracture. **B1.** Pre-operative computed tomography axial view showing displaced posterior facet of the calcaneus. **B2.** Pre-operative computed tomography coronal view showing displaced posterior facet of the calcaneus. **B3.** Pre-operative computed tomography sagittal view showing displaced posterior facet of the calcaneus. **C1.** Post-operative AP radiographs showing closed reduction and two crossed percutaneous Schanz pin fixation. **C2.** Post-operative oblique radiographs showing closed reduction and two crossed percutaneous Schanz pin fixation. **C3.** Post-operative lateral radiographs showing closed reduction and two crossed percutaneous Schanz pin fixation. **D1.** Control axial radiographs taken 1 year after surgery (AOFAS score: 91). **D2.** Control oblique radiographs taken 1 year after surgery (AOFAS score: 91). **D3.** Control lateral radiographs taken 1 year after surgery (AOFAS score: 91)

AP: Anteroposterior, AOFAS: American Orthopaedic Foot and Ankle Society

Table 1. Data regarding patients' gender, side and Sanders classification

Gender	**Female**	10	21.7
	Male	36	78.3
Side	**Right**	21	45.7
	Left	19	41.3
	Bilateral	6	13
Group preop sanders	**2**	8	15.4
	3	35	67.3
	4	9	17.3

The mean follow-up period for the patients was 47.5 months (range: 17.4-70.6 months). At the final follow-up, the mean AOFAS score was 83.25 (range: 47-96). The AOFAS scores were also analyzed separately according to the Sanders classification of fractures. The mean AOFAS scores were 74.3 for Sanders type 2 fractures, 84.7 for Sanders type 3 fractures, and 85.4 for Sanders type 4 fractures.

Among the 45 calcaneal fractures with an abnormal preoperative Böhler's angle, 33 cases (73%) achieved a postoperatively normalized Böhler's angle. In the 7 patients whose preoperative Böhler's angle was within normal limits, postoperative measurements also remained within the normal range. Each patient's preoperative and postoperative Böhler's angles were assessed individually, and a statistically significant improvement was observed between the preoperative and postoperative measurements ($p<0.05$).

The distribution of patients categorized according to Böhler's angle is presented in Table 2.

The relationship between fracture types and changes in Böhler's angle is presented in Table 3.

In the study, there was no statistically significant difference between the preoperative and postoperative Böhler's angles in patients with Sanders type 2 fractures ($p>0.05$). However, a statistically significant difference was observed in Sanders type 3 and Sanders type 4 fractures when comparing preoperative and postoperative Böhler's angle measurements ($p<0.05$).

Table 2. The distribution of patients according to Böhler's angle

All patients	Preop Böhler			
		Not normal, n (%)	Normal, n (%)	p-value
postBöhler	Not normal	12 (26.7)	0 (0.0)	**<0.001**
	Normal	33 (73.3)	7 (100.0)	

McNemar test

Table 3. Relationship between fracture types and changes in Böhler's angle

Sanders					
		2	3	4	p-value
		n (%)	n (%)	n (%)	
preBöhler	Normal	2 (28.6)	4 (57.1)	1 (14.3)	0.520
postBöhler	Normal	6 (15.0)	27 (67.5)	7 (17.5)	**<0.001**

The restoration of an abnormal Böhler's angle to normal values was also analyzed according to fracture type, and this improvement was found to be statistically significant across all fracture types. Among the three fracture types, the highest rate of normalization of Böhler's angle was observed in Sanders type 3 fractures.

No cases of nonunion, wound complications, thromboembolic events, or complications requiring revision surgery were encountered in any of the patients included in the study.

DISCUSSION

The management of DIACFs is complex and remains a subject of debate. The most important findings of the current study are that the crossed dual-pin fixation technique in a double-plane configuration for intra-articular calcaneal fractures provides both radiologically and clinically successful outcomes with low complication rates.

Conservative treatment of DIACFs is recommended for patients with medical comorbidities that pose a high surgical risk. However, this approach is associated with several complications, including subtalar arthritis, persistent pain, peroneal impingement syndrome, foot deformities, and flexor hallucis longus contracture (18,19). To mitigate these complications, ORIF techniques have been developed. However, ORIF is also associated with postoperative wound complications and nerve injuries (20), with reported complication rates ranging between 6% and 23% (21). Minimally invasive and percutaneous fixation techniques have been introduced to reduce the risk of complications. Various implant materials can be used for percutaneous fixation (22). In our study, Schanz screws, which are a more cost-effective alternative, were used as the fixation material.

Arora et al. (20) performed percutaneous fixation with K-wires in patients with DIACF and reported that, in radiological comparisons, postoperative Böhler's angle increased significantly in Sanders type 3 and type 4 fractures, while no statistically significant increase was observed in Sanders type 2 fractures. Chaniotakis et al. (23) described this technique as safe and effective, emphasizing that the quality of reduction is the most critical parameter influencing outcomes.

Mesregah et al. (24) treated Sanders type 2 and type 3 intra-articular calcaneal fractures using either closed or minimally open reduction followed by K-wire fixation. Their findings demonstrated excellent clinical outcomes with minimal soft tissue complications. Additionally, they reported no significant difference between fixation with K-wires and screws in terms of clinical results (24). Systematic reviews in the literature assessing the effectiveness of percutaneous fixation techniques in DIACF support the conclusion that this technique is a viable treatment option (25).

In our study, the crossed dual-pin fixation technique in a double-plane configuration was found to be an effective treatment method with low complication rates. This technique was particularly successful in the management of Sanders type 3 and type 4 fractures. However, in Sanders type 2 fractures, the outcomes were observed to be less satisfactory compared to the other fracture types.

The literature indicates that surgical restoration of Böhler's angle is associated with better long-term clinical outcomes (26). In our study, the AOFAS score was used, as it provides the best comparability across different studies (17).

In Arora et al. (20) study, the mean AOFAS score in patients who underwent fixation with K-wires was reported as 85.1. In contrast, El-Azab et al. (27) study found a mean AOFAS score of 75.8 in the K-wire fixation group. Another study

evaluating the short-term outcomes of DIACF treated with closed reduction and percutaneous K-wire fixation reported a satisfactory mean AOFAS score of 84 (28). Although numerical variations exist in the literature regarding the outcomes of this surgical technique, the majority of studies associate it with good to excellent results. In our study, the mean AOFAS score was 83.25, with more favorable outcomes observed in Sanders type 3 and type 4 fractures. This discrepancy was attributed to the less effective restoration of Böhler's angle in Sanders type 2 fractures compared to the other groups.

High rates of postoperative infection and wound complications have been reported in patients undergoing internal fixation via the extensile lateral approach. Sampath Kumar et al. (29) reported wound healing complications in 30.4% of their patients and deep infections in 13%. Similarly, in a larger case series involving 191 patients, the wound infection rate following ORIF was found to be 25% (30). In contrast to these high infection rates, various studies utilizing different percutaneous fixation techniques have reported significantly lower infection rates (12,20,28).

In our study, no cases of wound healing complications or infections were observed. This finding suggests that, with adequate preoperative preparation and strict adherence to sterile conditions, percutaneous fixation can achieve low complication rates, making it a safer alternative to open techniques.

Study Limitations

Our study has several limitations. The retrospective design and small sample size are among the primary limitations. Additionally, the use of only Böhler's angle as a radiological parameter and the relatively short follow-up period are constraints. Furthermore, the absence of a control or comparison group and the lack of a preoperative clinical scoring system for baseline assessment are additional limitations. However, a strength of this study is the categorization of outcomes based on the Sanders fracture classification, which enhances the clinical relevance of the findings. Additionally, all surgical procedures were performed at a single center by the same surgeon, representing another advantage and ensuring consistency in surgical technique and postoperative management.

CONCLUSION

In a conclusion, the crossed dual-pin fixation technique in a double-plane configuration can be effectively used in the treatment of DIACF, providing satisfactory radiological and clinical outcomes with low complication rates. This technique is particularly advantageous in Sanders type 3 and type 4 fractures, where better outcomes can be anticipated preoperatively.

ETHICS

Ethics Committee Approval: Data collection began after approval from the Clinical Research Ethics Committee of the University of Health Sciences Türkiye, Bakırköy Dr. Sadi Konuk Training and Research Hospital (approval no: 2018-03-23, date: 12.02.2018).

Informed Consent: Retrospective study.

FOOTNOTES

Authorship Contributions

Surgical and Medical Practices: M.G.B., Concept: B.B., M.G.B., Design: B.B., M.G.B., Data Collection or Processing: B.B., Analysis or Interpretation: B.B., Literature Search: B.B., Writing: B.B.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declare that this study received no financial support.

REFERENCES

1. Cao L, Weng W, Song S, Mao N, Li H, Cai Y, et al. Surgical treatment of calcaneal fractures of Sanders type II and III by a minimally invasive technique using a locking plate. J Foot Ankle Surg. 2015;54:76-81.
2. Hsu AR, Anderson RB, Cohen BE. Advances in surgical management of intra-articular calcaneus fractures. J Am Acad Orthop Surg. 2015;23:399-407.
3. Folk JW, Starr AJ, Early JS. Early wound complications of operative treatment of calcaneus fractures: analysis of 190 fractures. J Orthop Trauma. 1999;13:369-72.
4. Stulik J, Stehlik J, Rysavy M, Wozniak A. Minimally-invasive treatment of intra-articular fractures of the calcaneum. J Bone Joint Surg Br. 2006;88:1634-41.
5. Besch L, Schmidt I, Mueller M, Daniels-Wredenhagen M, Hilgert RE, Varoga D, et al. A biomechanical evaluation to optimize the configuration of a hinged external fixator for the primary treatment of severely displaced intraarticular calcaneus fractures with soft tissue damage. J Foot Ankle Surg. 2008;47:26-33.
6. Arastu M, Sheehan B, Buckley R. Minimally invasive reduction and fixation of displaced calcaneal fractures: surgical technique and radiographic analysis. Int Orthop. 2014;38:539-45.
7. Thermann H, Krettek C, Hüfner T, Schratt HE, Albrecht K, Tscherne H. Management of calcaneal fractures in adults. Conservative versus operative treatment. Clin Orthop Relat Res. 1998;353:107-24.
8. Barei DP, Bellabarba C, Sangeorzan BJ, Benirschke SK. Fractures of the calcaneus. Orthop Clin North Am. 2002;33:263-85.
9. Juliano P, Nguyen HV. Fractures of the calcaneus. Orthop Clin North Am. 2001;32:35-51.
10. Harnroongroj T, Tangmanasakul A, Choursamran N, Sudjai N, Harnroongroj T. Measurement technique of calcaneal varus from axial view radiograph. Indian J Orthop. 2015;49:223-6.

11. Dewall M, Henderson CE, McKinley TO, Phelps T, Dolan L, Marsh JL. Percutaneous reduction and fixation of displaced intra-articular calcaneus fractures. J Orthop Trauma. 2010;24:466-72.
12. Abdelgaid SM. Closed reduction and percutaneous cannulated screws fixation of displaced intra-articular calcaneus fractures. Foot Ankle Surg. 2012;18:164-79.
13. Schuberth JM, Cobb MD, Talarico RH. Minimally invasive arthroscopic-assisted reduction with percutaneous fixation in the management of intra-articular calcaneal fractures: a review of 24 cases. J Foot Ankle Surg. 2009;48:315-22.
14. Walde TA, Sauer B, Degreif J, Walde HJ. Closed reduction and percutaneous Kirschner wire fixation for the treatment of dislocated calcaneal fractures: surgical technique, complications, clinical and radiological results after 2-10 years. Arch Orthop Trauma Surg. 2008;128:585-91.
15. Sanders R, Vaupel ZM, Erdogan M, Downes K. Operative treatment of displaced intraarticular calcaneal fractures: long-term (10-20 years) results in 108 fractures using a prognostic CT classification. J Orthop Trauma. 2014;28:551-63.
16. Duramaz A, Polat Ö, İlter MH, Bayram B, Bayrak A, Baca E. Could percutaneous fixation with crossed Schanz pins be an alternative to open reduction in the treatment of intra-articular calcaneal fractures? Int Orthop. 2021;45:731-41.
17. Ibrahim T, Beiri A, Azzabi M, Best AJ, Taylor GJ, Menon DK. Reliability and validity of the subjective component of the American Orthopaedic Foot and Ankle Society clinical rating scales. J Foot Ankle Surg. 2007;46:65-74.
18. Rodriguez-Merchan EC, Galindo E. Intra-articular displaced fractures of the calcaneus. Operative vs non-operative treatment. Int Orthop. 1999;23:63-5.
19. Parmar HV, Triffitt PD, Gregg PJ. Intra-articular fractures of the calcaneum treated operatively or conservatively. A prospective study. J Bone Joint Surg Br. 1993;75:932-7.
20. Arora C, Jain AK, Dhammi IK. Outcome of percutaneous fixation of calcaneal fractures: a prospective analysis in an Indian population. J Foot Ankle Surg. 2019;58:502-7.
21. Yang Y, Zhao H, Zhou J, Yu G. Treatment of displaced intraarticular calcaneal fractures with or without bone grafts: a systematic review of the literature. Indian J Orthop. 2012;46:130-7.
22. Allegra PR, Rivera S, Desai SS, Aiyer A, Kaplan J, Gross CE. Intra-articular calcaneus fractures: current concepts review. Foot Ankle Orthop. 2020;5:2473011420927334.
23. Chaniotakis C, Genetzakis V, Samartzidis K, Siligardou MR, Stavrakakis I. Percutaneous fixation of displaced intraarticular fractures of the calcaneus. A retrospective case series study and a review of the literature. Injury. 2023;54:110966.
24. Mesregah MK, Shams A, Gamal O, Zaki EM. Clinical and radiological outcomes of minimally invasive reduction and percutaneous K-wire fixation for intra-articular calcaneal fractures. Orthopedics. 2020;43:97-101.
25. Wallin KJ, Cozzetto D, Russell L, Hallare DA, Lee DK. Evidence-based rationale for percutaneous fixation technique of displaced intra-articular calcaneal fractures: a systematic review of clinical outcomes. J Foot Ankle Surg. 2014;53:740-3.
26. Makki D, Alnajjar HM, Walkay S, Ramkumar U, Watson AJ, Allen PW. Osteosynthesis of displaced intra-articular fractures of the calcaneum: a long-term review of 47 cases. J Bone Joint Surg Br. 2010;92:693-700.
27. El-Azab H, Ahmed KFE, Khalefa AH, Marzouk AR. A prospective comparative study between percutaneous cannulated screws and Kirschner wires in treatment of displaced intra-articular calcaneal fractures. Int Orthop. 2022;46:2667-83.
28. Morsi IM, Khalifa AA, Hussien MA, Abdellatef A, Refae H. Evaluation of the short-term results of closed reduction and percutaneous K-wires fixation of displaced intra-articular calcaneal fractures (DIACF). Foot (Edinb). 2020;45:101740.
29. Sampath Kumar V, Marimuthu K, Subramani S, Sharma V, Bera J, Kotwal P. Prospective randomized trial comparing open reduction and internal fixation with minimally invasive reduction and percutaneous fixation in managing displaced intra-articular calcaneal fractures. Int Orthop. 2014;38:2505-12.
30. Backes M, Schepers T, Beerekamp MSH, Luitse JSK, Goslings JC, Schep NWL. Wound infections following open reduction and internal fixation of calcaneal fractures with an extended lateral approach. Int Orthop. 2014;38:767-73.