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Modified percutaneous fixation for displaced intra-articular calcaneal fractures

Deplase eklem içi kalkaneus kırıkları için modifiye perkütan tespit

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ABSTRACT

Objectives: This study aims to review the results of surgically treated displaced intra-articular calcaneal fractures with a fast, less complicated, and modified percutaneous technique.

Patients and methods: This retrospective study included 114 patients (86 males, 28 females; mean age 39 years; range, 16 to 66 years) admitted to our clinic for calcaneal fractures between May 2012 and June 2016 and operated using closed reduction and percutaneous fixation with two crossed Schanz pins. Trauma type, additional injuries, medical comorbidities, pre- and postoperative period, duration of operation, time to bone healing, complications, postoperative functional and radiological results were evaluated.

Results: The increase in the postoperative Bohler's angle measurements was statistically significant compared to preoperative values (p=0.001; p<0.01). According to Sanders classification, seven feet (5.3%) were type II, 76 feet (57.57%) were type III, and 49 feet (37.12%) were type IV. The mean American Orthopaedic Foot and Ankle Society (AOFAS) score was 80.4 (range, 47 to 92). According to Sanders classification, the mean AOFAS scores were 81.25 for type II, 81.88 for type III, and 80.19 for type IV. Mean duration of operation was 8±1.5 minutes.

Conclusion: Modified percutaneous fixation can give good results, even when open reduction is contraindicated. Maintaining the alignment and elevating the depressed intra-articular fragment may be sufficient for good mid-term results without anatomic reduction.

Keywords: Calcaneal fracture, intra-articular fracture, minimally invasive surgery, percutaneous fixation.

ÖZ

Amaç: Bu çalışmada deplase eklem içi kalkaneus kırıklarının hızlı, daha az karmaşık ve modifiye edilmiş perkütan bir teknikle cerrahi olarak tedavisinin sonuçları değerlendirildi.

Hastalar ve yöntemler: Bu retrospektif çalışmaya Mayıs 2012 ve Haziran 2016 tarihleri arasında kliniğimize kalkaneus kırığı nedeniyle başvuran ve iki çapraz Schanz vidası ile kapalı redüksiyon ve perkütan tespit kullanılarak ameliyat edilen 114 hasta (86 erkek, 28 kadın; ort. yaş 39 yıl; dağılım, 16-66 yıl) dahil edildi. Travma tipi, ek yaralanmalar, tıbbi komorbiditeler, ameliyat öncesi ve sonrası dönem, ameliyat süresi, kemik iyileşmesine kadar geçen süre, komplikasyonlar, ameliyat sonrası fonksiyonel ve radyolojik sonuçlar değerlendirildi.

Bulgular: Ameliyat sonrası Bohler açısı ölçümlerindeki artış ameliyat öncesi değerlere kıyasla istatistiksel olarak anlamlı idi (p=0.001; p<0.01). Sanders sınıflamasına göre yedi ayak (%5.3) tip II, 76 ayak (%57.57) tip III ve 49 ayak (%37.12) tip IV idi. Ortalama Amerikan Ortopedik Ayak-Ayak Bileği Derneği (AOFAS) skoru 80.4 (dağılım, 47-92) idi. Sanders sınıflamasına göre ortalama AOFAS skorları tip II için 81.25, tip III için 81.88 ve tip IV için 80.19 idi. Ortalama ameliyat süresi 8±1.5 dakika idi.

Sonuç: Modifiye perkütan teknik ile açık redüksiyonun kontrendike olduğu durumlarda bile iyi sonuçlar alınabilir. Dizilimin sağlanması ve çökmüş eklem içi parçanın yükseltilmesi, anatomik redüksiyon olmadan iyi orta dönem sonuçları için yeterli olabilir.

Anahtar sözcükler: Kalkaneus kırığı, eklem içi kırık, minimal invaziv cerrahi, perkütan tespit.

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Calcaneus is the most often fractured tarsal bone, with a percentage of 2% of all fractures, and 75% of these fractures involve articular surface.[1] For ideal functional results, anatomical reconstruction and restoration of the joint should be achieved with the restoration of articular congruity of the subtalar joint.[2] However, the role of subtalar joint may be exaggerated;[3] achieving subtalar joint surface restoration does not guarantee an asymptomatic foot.[4] Thus, anatomic reconstruction of the subtalar joint may not be the major factor for the outcome, as restoration of calcaneal height, width, and alignment of the hindfoot are also important prognostic factors.[5] After anatomic reduction and internal fixation, patients may require subtalar arthrodesis for symptomatic posttraumatic subtalar arthritis.[6] This happens because of the primary cartilage defect caused by axial impaction; this posttraumatic arthritis is regardless of the kind of treatment.[7]

Treatment options for displaced intra-articular calcaneal fractures (DICFs) are conservative methods, open reduction with plate fixation, minimally invasive techniques, and primary arthrodesis.[8] Open reduction and internal fixation (ORIF) with a standard L-shaped lateral approach have potential risks for hematoma, skin necrosis, wound infection, dehiscence, sural nerve injury, and hardware-related pain.[9] There can be 25% of wound complications, 21% of which require second surgeries.[10] In a recent study, it was shown that wound complications had a clinically significant negative effect on the outcome.[11] The extensile lateral approach may cause superficial wound edge necrosis in up to 14% of patients.[12] In addition, a second surgery can be required to treat soft tissue complications. The skin over the lateral calcaneal wall is prone to wound healing problems, and the unique plantar skin cannot be replaced properly once it is damaged.[13]

To minimize the soft tissue complications of extended lateral approach, and to treat the intra-articular fragments, minimally invasive techniques have been gaining popularity in recent years; however, an anatomical reduction is still an important issue to be discussed.[14] Long-term results of minimally invasive techniques remain questionable.[15] Abdelazeem et al.[14] reported that sinus tarsi approach and screws fixation can be used successfully to treat displaced Sander's type II and III fractures. Weber et al.[15] showed that short lateral subtalar approach and combined direct and percutaneous fixation can achieve anatomical reduction and fixation of displaced Sander's type II and III fractures. Percutaneous leverage techniques combined with Kirschner wire (K-wire) or screw fixation result in a decreased incidence of soft tissue complications and significant improvement in function. The advantages of these techniques are less early postoperative pain, a better range of motion (ROM), higher injured ankle functional scores, and fewer complications compared with open surgery. However, in some cases, percutaneous techniques have the potential disadvantage of inadequate anatomic reduction and, associated with this, a higher risk for subtalar osteoarthritis.[8] In this study, we aimed to review the results of surgically treated DICFs with a fast, less complicated, and modified percutaneous technique.

PATIENTS AND METHODS

A total of 114 patients (86 males, 28 females; mean age 39 years; range, 16 to 66 years) admitted to Orthopedics and Traumatology Department of Bakırköy Dr. Sadi Konuk Training and Research Hospital for calcaneal fractures between May 2012 and June 2016 were retrospectively evaluated. Inclusion criteria were *(i)* intra-articular calcaneal fractures, *(ii)* fractures treated by two cross Schanz pins, *(iii)* patients who had pre- and postoperative X-rays, and computed tomography (CT) scans, *(iv)* and patients with at least two years of follow-up. Exclusion criteria were *(i)* pathologic fractures, *(ii)* not all but uncastable type IIIB-C open fractures, *(iii)* conservative treatment, *(iv)* fractures fixed operatively except for two cross Schanz pins, *(v)* or patients with less than two years of follow-up. The study protocol was approved by the Bakırköy Dr. Sadi Konuk Training and Research Hospital Ethics Committee. A written informed consent was obtained from each patient. The study was conducted in accordance with the principles of the Declaration of Helsinki.

Trauma type, additional injuries, medical comorbidities, pre- and postoperative period, duration of operation, time to bone healing, complications, postoperative functional and radiological results were evaluated. Concomitant injuries and medical comorbidities were extracted from our institute's medical recording system.

Radiographically, all patients were evaluated by using pre- and postoperative X-rays, and CT scans. Fractures were classified by using Sanders classification. Bohler's angle was measured on pre- and postoperative X-rays. Functional results were evaluated by using the American Orthopaedic Foot and Ankle Society (AOFAS) hindfoot score. Preoperatively, depressed articular fragments that should be elevated and varus malalignment to be corrected were evaluated on CT scans.

Figure 1. (a) Deciding on entry point for posteromedial pin. **(b)** Introduction of posteromedial pin at medially cranial direction to laterally caudal direction. **(c)** Positioning of posteromedial pin before reduction maneuvers.

All patients were operated under either general anesthesia or spinal block, without tourniquet hemostasis. Patients were positioned on lateral decubitus position, fractured limb facing upwards. In this technique, two cross Schanz pins are introduced from posteromedial and posterolateral. The first pin was inserted posteromedially. With the aid of a C-arm, entry point for this pin was decided (Figure 1a). It was directed in a manner that when introduced posteromedially, it went directly from tuber calcanei to just beneath the fragment that should be elevated (Figure 1b). At the beginning, this pin was introduced in parallel to the fragment that should be elevated, which is generally nearly at direct angle from tuber calcanei, and also it was directed from medially to laterally to correct varus alignment (Figure 1c). When this pin reached the determined point, varus alignment was corrected by moving the handle of the power driver from medially to laterally, at the same time, the surgeon pushed with his/her thumbs from the anterior and posterior aspects of calcaneus on the lateral side of the foot, and made distraction with other four fingers from the medial side of the foot to correct varus angulation (Figure 2). After varus correction, the direct angle was corrected by moving the handle of power driver from cranial to caudal and the pin became parallel with the sole, by this, the depressed fragment was elevated (Figure 3). After achieving the reduction, the pin was moved distally taking care not to penetrate the calcaneocuboid joint (Figure 3). After the insertion of the first pin, the point for the posterolateral pin was decided again by using C-arm. The posterolateral pin was also inserted from tuber calcanei, and through beneath the residual impacted fragment, and parallel to it. But this time, it was used only for the depressed fragment, and after the elevation of the residual depressed fragment, it was again introduced distally (Figure 4). The insertion points for Schanz pins were closed by using absorbable sutures, and long leg cast was applied by manipulating from the Schanz pins and forefoot.

Figure 2. Correction of varus deformity by moving pin's base from medial to lateral as well as surgeon's manual manipulation.

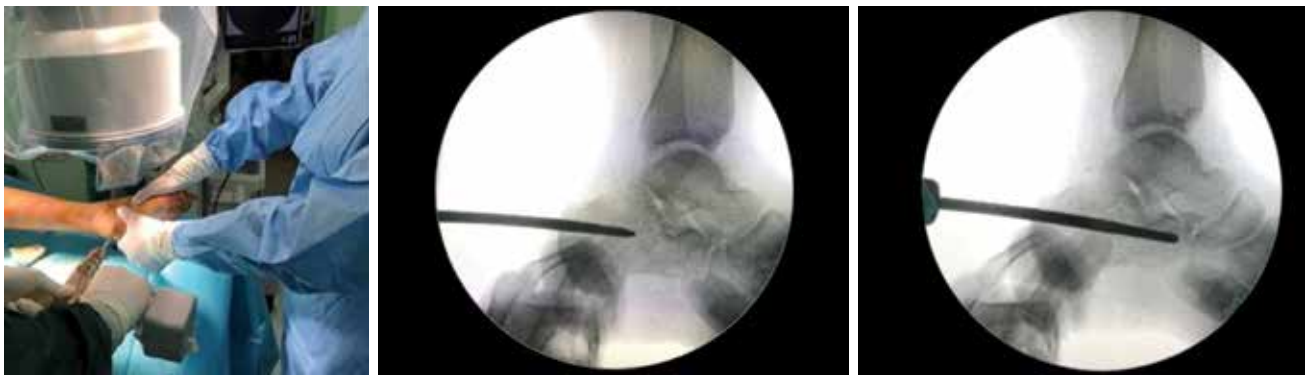

Figure 3. Elevation of depressed fragment by moving power engine from cranial to caudal and intraoperative scope control, and final position of posteromedial pin.

Figure 4. Introduction of posterolateral pin and final intraoperative control.

Figure 5. Preoperative X-rays and computed tomography scans of a 30-year-old male patient.

Postoperative X-rays and CT scans were taken just after the operation, and the follow-up control X-rays were taken at the 6th, 8th, 10th, and if required, on the 12th week. Later on, patients were controlled at the 3rd, 6th, 12th, 18th, and 24th months with routine X-rays. At the final follow-up, a final CT scan was also taken (Figures 5 and 6).

Statistical analysis

The statistical analysis was performed using the Number Cruncher Statistical System 2007 (NCSS, LLC, Kaysville, Utah, USA). Wilcoxon signed-rank test was used in pre- and postoperative evaluations of descriptive statistical methods (mean, standard deviation, median, frequency, ratio, minimum, maximum) as well as non-normal distribution parameters when the study data were evaluated. Statistical significance was at least $p<0.05$.

RESULTS

A total of 18 patients were bilateral, while the number of operated calcaneal fractures was 132. Mean age was 40 years (range, 17 to 66 years) for males, 37 years (range, 16 to 58 years) for females, and 39 years (range, 16 to 66 years) overall. Mean duration of follow-up was 42.33±18.33 months (range, 24 to 69 months).

Figure 6. Early postoperative X-rays and 30-month follow-up of same patient.

Forty-four patients were smokers (38.5%), while 13 were diabetics (11.4%). Three patients suffered from chronic renal failure (2.6%). Six patients were drug addicts (5.2%). Sixty patients (45.45%) had additional orthopedic injuries.

The increase in the postoperative Bohler's angle measurements compared to preoperative values was statistically significant (p=0.001; p<0.01) (Table I). The distribution of patients with abnormal angle was none for type II, 27% for type III (21/76), and 53% for type IV (26/49).

According to Sanders classification, seven feet (5.3%) were type II, 76 feet (57.57%) were type III, and 49 feet (37.12%) were type IV.

Mean AOFAS score was 80.4 (range, 47 to 92). According to Sanders classification, the mean AOFAS scores were 81.25 for type II, 81.88 for type III, and 80.19 for type IV.

Four feet had wound-related complication (3.02%). All resolved by appropriate treatment. Six feet (4.54%) needed a second surgical procedure. Five patients had subtalar arthrodesis, while one patient had lateral wall exostectomy.

Mean duration of operation was 8±1.5 minutes. This duration did not show any statistical significance between various fracture types. Mean time to bone healing was 8.43 weeks (range, 7 to 12 weeks). Passive ROM started at sixth-eighth weeks. Weight bearing started at 8^{th}-10^{th} weeks.

DISCUSSION

Treating DICFs is challenging because the calcaneus has a complex bone morphology, fractures are mostly comminuted, and the soft tissue around the bone is fragile. In our study, we aimed to evaluate the results of surgically treated displaced intra-articular calcaneal fractures with a fast, less complicated, and cheap new modified percutaneous technique which has outcomes compatible with literature.[16] Totally, 60-85% good-to-excellent results have been reported after plate fixation; however, with a significant risk for soft tissue complications.[17] It devascularizes the central and anterior part of the calcaneal lateral wall where 45% of the total blood supply of the calcaneus enters.[18] In addition, the lateral wall of the calcaneus is subcutaneous and implants here can lead to wound healing complications. To overcome the wide range of complications associated with extended lateral approach, indirect or minimally invasive fixation techniques have been developed.[8] Percutaneous techniques offer less pain and earlier postoperative mobilization, in addition to preservation of blood supply and preventing wound infection, dehiscence, and necrosis. This results in better hindfoot mobility, higher functional scores, a shorter recovery period,

TABLE I

Evaluation of Bohler's angle (n=132)

	Preoperative					Postoperative					
	n	%	Mean±SS	Median	Min-Max	n	%	Mean±SS	Median	Min-Max	*p*
Bohler's angle			12.6±8.5	12	-39 - 24			30.7±10.4	30	12-49	0.001*
Bohler's angle distribution											
Low	119	91.2				16	12.12				
Normal (20-40)	13	9.8				85	64.4				
High	-	-				31	23.48				

SS: Standard deviation; Min:Minimum; Max: Maximum; * p<0.01; Wilcoxon signed-rank test.

and a lower incidence of complications compared with ORIF.[19]

In the current study, closed reduction and percutaneous fixation with two oblique Schanz pins were used for DICFs, with minimal wound problems in a short operation time even in patients with smoking addiction, diabetes mellitus, obesity, drug abuse, and elder age.

In the current study, only three feet (2.27%) developed superficial infection, and one deep infection (0.75%). The total wound-related complication rate was 3.02%. This wound-related complication rate is very compatible to, and sometimes better than the current literature. In a recent study, Majeed et al.[20] reviewed the studies comparing minimally invasive methods and ORIF. In this review, wound-related complication rates were 0-13% (mean, 4.3%) for minimally invasive methods and 11.7-35% for ORIF group. However, these rates differ in non-compared studies. Rawicki et al.[21] reported 17.6% deep infection rate after sinus tarsi approach. Moreover, Gamal et al.[22] used K-wires for fixation and reported a 9.4% superficial infection rate. Even with the balloon-assisted percutaneous techniques, 10% of superficial infection can be seen.[23] We believe that our low infection rates are due to short operation time and minimal surgical dissection.

The need for revision surgery was also evaluated. In the current literature, the need for revision surgery changes according to the chosen method. For minimal invasive methods, it varies between 1.9% and 41.7% and for ORIF between 1.7% and 23.1%.[24] According to our data, six patients (4.54%) needed revision surgery. Five patients had subtalar arthrodesis, while one patient had lateral wall exostectomy. These rates are comparable with the literature.

Functional outcome was assessed by using the AOFAS ankle-hindfoot scoring system. Majeed et al.[20] reviewed the literature for minimally invasive methods versus ORIF. They concluded that the reported mean AOFAS score was 84.9 in the minimally invasive method and 81.3 in the ORIF group. In the Veltman's review, mean AOFAS score was 86.4 for percutaneous treatment and 73.7 for ORIF group.[25] Our mean AOFAS score was 80.4. Our mean AOFAS score is slightly lower from the literature when compared with minimally invasive surgery reviews, but similar or better from ORIF reviews. In addition, an mean good result could be achieved in all Sanders classification types.

In a comparative cohort study performed by Biz et al.,[26] the authors compared ORIF, percutaneous fixation with K-wires, and percutaneous fixation with screws. They reported AOFAS scores as 82 for ORIF, 79 for percutaneous screw fixation, and 74 for K-wire fixation with an mean complication rate for percutaneous fixations as 21%. In another study concerning percutaneous techniques, Vittore et al.[23] used balloon-assisted reduction and pin fixation. Their mean AOFAS score was 80.05. Our scores and complication rates are better than these results. Shih et al.[27] achieved slightly higher AOFAS scores with their percutaneous technique than the current study, with a mean score of 84.6. However, in their study, they used sinus tarsi-like approach to elevate articular surface and used calcium sulfate cement augmentation. Battaglia et al.[28] also reported better scores with the percutaneous technique. Their mean AOFAS score was 85. However, again, they used an additional incision, for this time to reduce the posterior facet. In addition, this technique depended on a special device.

Mean duration of operation was 8±1.5 minutes. This duration is very short according to the current literature. Minimal invasive methods have shorter duration of operation than ORIF. In the literature, the shortest duration that we could find was 47.3±20 minutes.[28] Our mean duration of operation is far better than the current literature. This yields less use of anesthetics, less X-ray exposure, and more feasible use of the operation room. With the use of only two Schanz pins and the short duration of operation, this method becomes more cost-effective than others.

The literature has shown that the operative reconstruction of Bohler's angle is associated with better functional long-term outcome.[2,5] In the current study, Bohler's angle evolved from 12.60±8.48° to 30.72±10.35°, which is statistically significant. This progress in the angle is consistent with the literature. Postoperative distribution of abnormal Bohler's angle differed between Sanders types, but outcome scores of these types were similar. We believe that this was due to the number of type II fractures, which was very low compared with types III or IV. Secondly, all fractures had an angular progression after the operation although they could not reach normal values.

In the current study, time to operation and postoperative stay were not considered since 60 of the 114 patients had additional orthopedic injuries that needed operative intervention, and this affected waiting time to operation and discharge from the hospital.

The limitations of this study are the retrospective design, having achieved only mid-term results, and the lack of a control group. Our results should be

supported by prospective randomized studies in the long-term.

In conclusion, we believe that modified percutaneous fixation can be used succesfully even when the open reduction is contraindicated. Maintaining the alignment and elevating the depressed intra-articular fragment may be sufficient for good mid-term results, without anatomic reduction.

Declaration of conflicting interests

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