Calcaneus bone intra-articular fracture treatment by the closed reduction and percutaneous fixation with cannulated screw method in high-risk patients: A pilot trial

Adel Ebrahimpour, Mohammad Hosseini Chegini, Mehrdad Sadigh, Mohammad Ali Okhovatpour, Mohammadreza Minator Sajjadi, Mohammad Ashkzari

Ebrahimpour A, Chegini MH, Sadigh M, et al. Calcaneus bone intra-articular fracture treatment by the closed reduction and percutaneous fixation with cannulated screw method in high-risk patients: A pilot trial. J Clin Diag Treat 2018;1(1): 39-42.

OBJECTIVE: Debate surrounding the methods for optimal treatment of calcaneal fractures is controversial. One method, closed reduction and percutaneous fixation, can restore the height, width, length and shape of the hindfoot by restoring the orientation of the calcaneal posterior facet. The aim of this study was to evaluate the treatment of intra-articular fractures of the Calcaneus bone with this method, especially in patients unsuitable for open reduction surgery.

METHOD: 49 patients with intra-articular fractures underwent closed reduction and percutaneous fixation surgery between 2014 and 2016 in Taleghani Hospital. After 12 months of follow up, pain, functional outcome, range of motion, and change in footwear were evaluated with the use of the criteria from the American Orthopedic Foot and Ankle Society (AOFAS). Bohler's and Gissane's angles were recorded before and after surgery, and 12 months later. A visual analog scale (VAS) was recorded for the patient, along with their return to employment status, and post-operative infection status.

RESULT: Out of 49 patients, 42 were male and 7 were female. All cases demonstrated bony union, with an average Bohler's angle of 25.92 ± 7.93 and Gissane's angle of 115.39 ± 11.24. At the 12 months' follow-up, the mean values of the AOFAS score were 73.3 ± 7.08. The changes in Bohler's angle, VAS and AOFAS score did not differ significantly between patients with blister and without blister, and also between the smokers and non-smokers sub-groups. Neither deep infection nor osteomyelitis was seen.

CONCLUSION: Closed reduction and percutaneous fixation of calcaneus fractures using cannulated screws can be a safe and effective method for treating calcaneus fractures.

Key Words: *Intra-articular calcaneus fractures; Percutaneous screw fixation; Sanders classification; Closed reduction*

The treatment of calcaneal fractures (Cfs) plays a major role in the processes of recovery and improvement in patients (1). Cfs make up 60% of tarsal bone fractures (2) and usually affect adult males, and have a high socio-economic cost (3). The fracture mechanism is typically high energy axial loading of the bone caused by a fall from a height or a road traffic accident (4). Regarding the involvement of the articular surface, Cfs is descriptively categorized into extra-articular and intra-articular types. The compression of the talus against the calcaneus is responsible for the intraarticular type, while extra-articular fractures are avulsion injuries arising from twisting or shearing forces. The outcome of extra-articular fractures is, on average, better than intra-articular types. The classification system was defined by Sanders, based on CT scan findings (5).

The optimal treatment of intra-articular fractures of the calcaneus is under debate. Open reduction and internal fixation (ORIF), using a combination of plates and screws, is considered a standard treatment for displaced intra-articular fractures, providing satisfactory outcomes in the majority of patients. However, ORIF is contraindicated in smokers and patients with poor soft tissue condition or vascular insufficiency (6-8). Various subsequent complications have also been frequently reported (9).

The percutaneous approach has been recommended as combining the benefits of operative intervention with a reduced risk of infection through small incisions (10). Following the above concerns, it was decided to evaluate the outcomes of closed reduction and percutaneous fixation of intra-articular calcaneus fractures using cannulated screws in this study.

MATERIAL AND METHODS

Patients and settings

In this caseseries study, 49 patients with intra-articular Cfs underwent closed reduction and per-cutaneous fixation with cannulated screws. Cases were selected via convenience sampling among patients referred to Taleghani hospital, affiliated to Shahid Beheshti University of Medical Sciences (SBMU), Tehran, Iran, from July 2014 to May 2016. The exclusion criteria were defined as aged under 12, fractures in other locations, extra-articular fractures, and type I fractures based on Sander's classification. The study protocol was approved by the Ethics Committee of SBMU.

Demographic and clinical parameters were recorded. Plain radiography, including the ankle series (anteroposterior, lateral view), as well as an axial (Harris) view, was obtained. Bohler's and Gissane's angle were measured on X-rays. Furthermore, a spiral CT scan of the hindfoot was performed to determine Sander's classification.

Surgical technique

Patients were stabilized on a radiolucent operating table in the lateral decubitus position (Figure 1). C-arm was properly placed in the imaging setup for obtaining X-rays in the sagittal and axial di-rections. Surgery was conducted by a single attending orthopedic surgeon in the following 4 steps:

Disimpaction

A pin of size 4.5 mm was inserted from the lateral side into the calcaneal tuberosity. With manu-al longitudinal traction through the forefoot to calcaneus and Varus-Valgus levering, calcaneus length and dis-impaction of the fracture fragments was achieved (Figure 1).

Figure 1) *Lateral decubitus position and disimpaction*

Reduction

In the joint depression type, by inserting a 2.5 or 3 mm pin percutaneously,

Taleghani Hospital, Research Development Unit, Department of Orthopedic Surgery, Shahid Beheshti University of Medical Science, Tehran, Iran

Correspondence: Mohammadreza Minator Sajjadi, Taleghani Hospital, Research Development Unit, Department of Orthopedic Surgery, Shahid Beheshti University of Medical Science, Tehran, Iran. Telephone: 09123377215, e-mail arashsajadi@sbmu.ac.ir

Received: March 31, 2018, Accepted: April 02, 2018, Published: April 09, 2018

the fragments of the posterior facet were levered into its anatomical position. The joint surface reduction was monitored under the guidance of C-arm fluoroscopy. At the same time, all attempts were made to restore acceptable Bohler's and Gissane's angles (Figure 2).

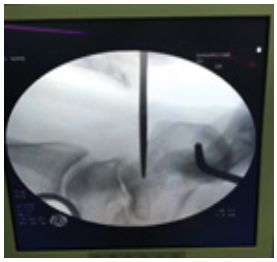


Figure 2) *Bohler's and Gissane's angles*

Subsequently, the whole construction was fixed with one or two 3.5 or 4 mm cannulated screws introduced to the undersurface of the posterior facet to prevent articular surface collapses (Figure 3). In some cases, this process could be achieved by inserting one or two 3.5 or 4 mm cannulated screws through the postero-inferior aspect of the calcaneus distal to insert the Achilles tendon to the undersurface of the posterior facet in the oblique direction.

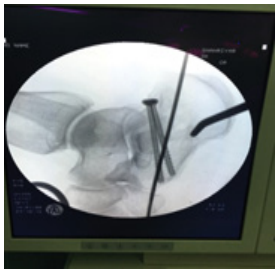


Figure 3) *Reduction of posterior facet*

Re-impaction

This step involved lateral compression of the bone in order to reduce calcaneal width and prevent lateral impingement. After assuring a favorable reduction, a suitable number of 3.5 mm screws were transversally placed from the lateral side (trampoline screw) along the posterior articular facet into the sustentacular fragment, which is termed the Constant fragment, using the Borden view. A proposed method to reduce the radiation time involves locating the Trampoline screw properly by putting 2 pins in the anterior and the posterior border of the fibula, and using the central of these 2 pins to determine the correct entrance location (Figure 4, 5A and 5B).

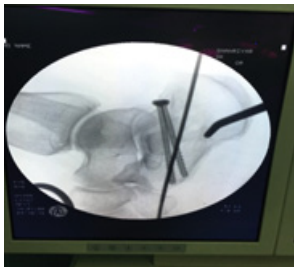
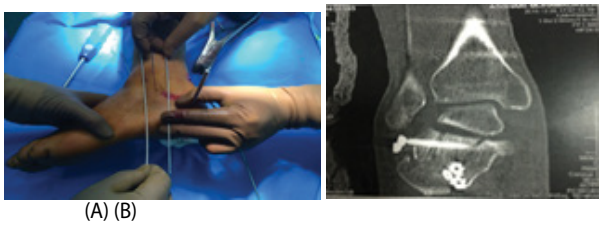


Figure 4) *Fixation of posterior facet*



(A) (B)

Figure 5) A and B: *Trampoline screw*

Length restoration

In the last step, the calcaneal tuberosity was fixed to the anterior part of the calcaneus with one or two 6.5 mm cannulated screws percutaneously to maintain bone length (Figure 6).

Figure 6) *Length restoration*

Post-op care and follow-up

A short leg posterior splint was applied. Patients were advised to only engage in non-weight-bearing activities for the first 6 weeks, and to perform isometric exercises of the cuff muscles. After 6 weeks, the posterior splint was removed during the day but applied at night. Patients carried out toe-touch weight bearing with passive and active exercises of the ankle and toes during the day. Full weight bearing started after 12 weeks. After one year, Bohler's and Gissane's angle were measured again. In the final visit, the reduction and union status, along with the occurrence of complications (such as screw head irritation and infection) were recorded. Patients were also requested to report their severity of pain using the Visual Analog Scale (VAS). To determine the outcome of treatment, the American Orthopedic Foot and Ankle Score (AOFAS) questionnaire was completed for all patients as part of the final visit. In addition, the extent of previous functional level recovery was assessed using the Tegner activity scale. The patient's ability to return to work was also examined.

STATISTICAL ANALYSIS

Continuous variables were statistically summarized in terms of mean ± SD, or as a median with interquartile and total ranges. Categorical data are presented numerically (percentage). The Shapiro-Wilk's W-test was used to assess the normality assumption of continuous variables. One way repeated measure ANOVA was conducted to examine the differences of continuous variables at three time points. Paired t-tests or Wilcoxon signed rank tests, wherever appropriate, were used to compare the continuous variables between two time points. Generalized Estimating Equation (GEE) models were applied to examine the associations between Sanders classification types and changes in the study outcomes of. GEE models included two main effects, and the interaction of these effects. The same models were used to examine the associations between both smoking status and blister status and study outcomes over the course of the study.

RESULTS

49 patients with Cfs were treated, 42 males (85.71%) and 7 females (14.28%). The mean ± SD age of patients was 38.04 ± 13.75, with a range of 12 to 67 years. The other demographic data are shown in Table 1.

TABLE 1

Demographic and clinical parameters

Sex	
Male	42 (85.71%)
Female	7 (14.28%)
Age	38.04 ± 13.75
Smoker n (%)	22 (44.90%)
Opium addict n (%)	4 (8.16%)
Diabetes mellitus	2 (4.08%)
Cause of Fx	
Falling down	41 (83.67%)
Traffic accidents	8 (16.33%)
Type of Cf	
Tongue type	17 (34.69%)
Joint depression	32 (65.31%)
Sanders 'Classification	
Type II	15
Type III	29
Type IV	5

The median interval between the occurrence of fracture and surgery was four days. Only 4 patients had superficial infections. Post-operative swelling of the surgery site was observed in 23 cases (46.94%). At the final visit, 33 patients (67.35%) complained of pain caused by the screw head. 26 patients (53.06%) returned to their job within 12 months after the surgery (Post-op). The median VAS was 4 and the median. Tegner activity level scale changed from 3 to 2, showing a significant reduction between pre-operation and the final visit (P<0.0001).

The mean AOFAS was 73.31 ± 7.08, 12 months after surgery (range: 61 to 95). The mean ± SD Bohler's angle significantly increased over the study from 20.20 ± 10.43 (range: 0° to 42°) to 28.26 ± 7.01 (range: 5° to 40°) (P<0.0001). At the final visit, the mean Bohler's angle value was 25.92 ± 7.93 (range: 10° to 41°), showing a significant difference between post-op and the final visit (P=0.004). The mean Gissane's angle was significantly different at the three time points (P<0.0001). The mean ± SD Gissane's angle Pre-op was 129.10 ± 16.17, which was significantly reduced to 114.04 ± 9.42 (P<0.0001), and it was 115.39 ± 11.24 at the final visit. There was no significant difference of these values Post-op in comparison with the final visit.

There were no significant differences seen among Sanders classification types in VAS, AOFAS, Post-op inflammation status, and return to employment within 12 months after surgery (Table 2). The pattern of changes in Gissane's angle values did not differ significantly over time among the Sanders classification types (Table 2). The mean percentage reduction of Gissane's angle values from Pre-op to Post-op was 9.06%, 13.02% and 12.69% in Sanders classification types II, III and IV, respectively (Table 2). A significant reduction was observed from Pre-op to Post-op in type III (P<0.001).

The changes of Bohler's angle scores differed over the study period among three Sanders classi-fication types (P=0.01), and type IV (compared to type III) had an additional increase (12.87°) in Bohler's angle value from Pre-op to final visit (P=0.02). In all types, Bohler's angle scores sig-nificantly increased from pre-surgery to post-surgery (Table 2). The changes of Tegner activity level scale values were similar over time among three Sanders classification types. A significant reduction was observed in the Tegner activity level scale values at the final visit compared to Pre-op in all types, as shown in Table 2. No significant difference was observed between smokers and non-smokers in VAS, AOFAS, post-op inflammation status, and return to employment within 12 months Post-op, and the changes in Gissane's angle (Table 2).

The mean percentage reduction of Gissane's angle values from pre-op to post-op was 14.62% and 8.21% in the smokers and non-smokers groups (Table 2). A significant reduction was observed from Pre-op to Post-op in both groups (p<0.001 and p=0.001) (Table 2). No significant changes were observed from Post-op to final visit in either group (Table 2). Both groups were similar in the changes of Bohler's angle scores over the study period, which increased significantly from Pre-op to Post-op (P<0.001) (Table 2). The changes in Tegner activity level scale values were similar over time between both groups (Table 2).

A significant reduction was observed in the Tegner activity level scale values at the final visit, compared to Pre-op, in both the smokers and non-smokers groups (P=0.01, P<0.001, respectively). There was no significant difference between patients with and without blisters in VAS, AOFAS, Post-op inflammation status, return to employment within 12 months Post-op, and the changes of Gissane's angle (Table 2). The mean percentage reduction of Gissane's angle values from Pre-op to Post-op was 11.46% and 11.83% in patients with and without blisters, respectively (Table 2).

A significant reduction was seen from Pre-op to Post-op in both these groups (P<0.001). No significant changes were observed from Post-op to final visit in both patients with and without blisters (Table 2). The changes of Bohler's angle scores did not alter significantly over time between patients with and without blisters, and in both groups, Bohler's angle scores increased significantly from Pre-op to Post-op (P<0.001 and P=0.003) (Table 2).

The changes in Tegner activity level scale values were similar over time between patients with blisters and patients without blisters. A significant reduction was observed in the Tegner activity level scale values at the final visit compared to Pre-op in both patients with and without blisters (P=0.003 and P<.001, respectively).

DISCUSSION

The best method for the treatment of Cfs still remains controversial (11,12). The use of minimally invasive methods has been described by Westhues et al. (13). The use of minimally invasive techniques and screw fixation techniques has been evaluated in several studies (14-17).

Although the goal of Cf treatment is the reconstruction of the posterior facet and the normal shape of the heel, it seems that it is not necessary to have an anatomical reduction in the posterior facet in order to obtain satisfactory clinical results; rather the reconstruction of the normal form of the hindfoot is much more important (18).

The relationship of Bohler's angle with the results of intra-articular fractures of the calcaneus has been proven in previous studies (19). The Bohler's angle significantly increased after surgery and remained in a normal range one year after surgery. Also, Gissane's angle decreased Post-op and interestingly, with regard to the downward and upward changes, its angle remained within the range of normal values at the 12-month stage (20). According to these results, closed reduction and percutaneous fixation with cannulated screw is able to

TABLE 2

Study outcomes according to Sanders classification, Smoking status, and blister status

	Sanders classification			Smoking status		Blister	
Tegner activity level scale	Type II	Type III	Type IV	Smoker and addict (n=26)	Non-smoker (n=23)	Patient with blister (n=22)	Patient without blister (n=27)
VAS	3; (2 to 4.5); (1 to 6)	4; (3 to 5); (2 to 6)	3; (2 to 4); (2 to 4)	4; (2.75 to 5); (2 to 6)	4; (3 to 4); (1 to 6)	4; (2.75 to 4.25); (2 to 6)	4; (3 to 4); (1 to 6)
AOFAS	72.94 ± 8.08	73.74 ± 6.81	72.20 ± 6.02	72.62 ± 6.11	74.09 ± 8.12	74.91 ± 7.67	72.00 ± 6.42
Prior to surgery	3; (2 to 3.5); (2 to 4)	3; (2 to 4); (2 to 4)	3; (3 to 3); (3 to 3)	3; (3 to 4); (2 to 4)	3; (2 to 3); (2 to 4)	3; (2 to 3.25); (2 to 4)	3; (2 to 4); (2 to 4)
Final visit	2; (1 to 3); (1 to 4)	3; (2 to 3); (1 to 4)	2; (1.5 to 3); (1 to 3)	3; (2 to 3); (1 to 4)	2; (2 to 3); (1 to 3)	3; (2 to 3); (1 to 3)	2; (2 to 3); (1 to 4)
Bohler's angle							
Prior to surgery	18.24 ± 2.53	22.11 ± 2.00	16.60 ± 4.66	20.77 ± 9.34	19.56 ± 11.72	20.77 ± 11.40	19.74 ± 9.76
After surgery	28.85 ± 5.88	27.85 ± 5.88	31.20 ± 5.76	28.42 ± 8.27	28.09 ± 5.44	27.82 ± 7.93	28.63 ± 6.30
Final visit	26.53 ± 8.60	24.44 ± 7.29	31.80 ± 7.33	26.69 ± 9.50	25.04 ± 5.76	25.91 ± 8.02	25.92 ± 8.00
Gissane's angle							
Prior to surgery	124.06 ± 15.62	131.67 ± 16.42	132.40 ± 15.58	131.35 ± 16.92	126.56 ± 15.25	129.27 ± 15.15	128.96 ± 17.24
After surgery	112.82 ± 9.09	114.52 ± 10.26	115.60 ± 6.23	112.15 ± 8.96	116.17 ± 9.67	114.45 ± 10.25	113.70 ± 8.87
Final visit	114.00 ± 9.86	117.00 ± 12.07	111.40 ± 11.61	113.73 ± 11.48	117.26 ± 10.91	117.54 ± 10.88	113.63 ± 11.42
Post-surgery inflammation, N (%)	7 (41.18%)	13 (48.15%)	3 (60.00%)	13 (50.00%)	10 (43.48%)	10 (45.45%)	13 (48.15%)
Return to job, N (%)	10 (58.82%)	14 (51.85%)	2 (40.00%)	12 (46.15%)	14 (60.87%)	12 (54.54%)	14 (51.85%)

restore acceptable hindfoot shape and height, with the final Bohler's and Gissane's angles in normal ranges.

These results can be compared with the findings of studies which used similar less invasive fixation methods (18) and internal fixation with a wide lateral approach (21). There are significant differences between studies in non-surgical values (22). Non-surgical treatment methods have been associated with poor clinical therapeutic outcomes (11). Levine et al. observed that subtalar joint movement is maintained with an anatomical reduction using percutaneous fixation (17). Abdelgaid et al. fixed calcaneus fractures using 4 mm and 6 mm cannulated screws and observed no cases of wound infection or other complications during a 29 month follow-up period, with only three cases of reduction loss due to early weight gain reported (16). Also, Dewall et al. used 3.5 mm or 4 mm cannulated screws and their results were compared to the ORIF method. The results presented a significant difference between the two methods in terms of the incidence of wound complications and deep infection (10). ORIF is supported by many reports, as one type of treatment for most intra-articular calcaneus fractures, but rate of complication remains noteworthy (23,24).

In this study, high-risk patients with intra-articular Cfs can be safely managed using percutaneous reduction and fixation. The changes of Bohler's and Gissane's angle, VAS and AOFAS did not differ significantly between patients with and without blister, and the differences between smokers and non-smokers is consistent with Hammond's study (15). Smoking and blisters did not affect return to employment within the 12 months after surgery. Cfs is associated with bad skin conditions like blisters, which is challenging for many orthopaedics surgeons. Most studies indicate the impact of fracture blisters, especially on delays in surgical management and higher risks of complications (25).

In this study, the presence of blisters did not affect delays in surgery. No Postop complications were observed in this group. The most common complication of this technique was skin irritation. It occurred due to inappropriate countersinking of the screw heads. This issue led to superficial infections in some cases. This study was limited by its small sample size. Long term follow-up could be helpful in evaluating the amount of subtalar arthrosis, compared with other techniques.

CONCLUSION

Closed reduction and percutaneous fixation using cannulated screws can be used in cases involving undesirable soft tissue conditions with a low risk of infection. Skin problems and being smokers are relative contraindications of open surgery.

Since this method is able to restore the heel shape and the posterior facet reduction as much as other less invasive techniques, it can be applied as an alternative technique suitable for patients with unfavorable conditions in open surgical procedures and internal fixation.

REFERENCES

1. Wei N, Yuwen P, Liu W, et al. Operative versus nonoperative treatment of displaced intra-articular calcaneal fractures: A meta-analysis of current evidence base. Medicine 2017;96:e9027 .
2. Palmersheim K, Hines B, Olsen BL. Calcaneal fractures: An update on current treatments. Clinics in podiatric medicine and surgery 2012;29:205-220.
3. Mitchell M, McKinley J, Robinson C. The epidemiology of calcaneal fractures. The Foot 2009;19:197-200.
4. Dhillon MS, Bali K, Prabhakar S. Controversies in calcaneus fracture management: A systemat-ic review of the literature. Musculoskeletal surgery 2011;95:171-181.
5. Barei DP, Bellabarba C, Sangeorzan BJ, et al. Fractures of the calcaneus. Orthope-dic Clinics of North America. 2002;33:2632-85.
6. Rammelt S, Zwipp H. Calcaneus fractures: Facts, controversies and recent developments. Injury. 2004;35:443-61.
7. Jain S, Jain AK, Kumar I. Outcome of open reduction and internal fixation of intraarticular calcaneal fracture fixed with locking calcaneal plate. Chinese Journal of Traumatology 2013;16:355-60.
8. Zeman P, Zeman J, Matejka J, et al. Long-term results of calcaneal fracture treatment by open reduction and internal fixation using a calcaneal locking compression plate from an extended lateral approach. Acta chirurgiae orthopaedicae et traumatologiae Cechoslovaca 2008;75:457-464.
9. Ding L, He Z, Xiao H, et al. Risk factors for postoperative wound complications of calcaneal fractures following plate fixation. Foot & ankle international. 2013;34:1238-1244.
10. DeWall M, Henderson CE, McKinley TO, et al. Percutaneous reduc-tion and fixation of displaced intra-articular calcaneus fractures. J orthop trauma 2010;24:466-472.
11. Buckley R, Tough S, McCormack R, et al. Operative compared with nonoperative treatment of displaced intra-articular calcaneal fractures: A prospective, randomized, controlled multicenter trial. J Bone Joint Surg Am 2002;84:1733-1744.
12. Schepers T, van Lieshout EMM, Van Ginhoven TM, et al. Current concepts in the treatment of intra-articular calcaneal fractures: Results of a nationwide survey. Int Orthop 2008;32:711-715.
13. Essex-Lopresti P. The mechanism, reduction technique, and results in fractures of the os calcis. Br J Surg 1952;39:395-419.
14. Tornetta P. Percutaneous treatment of calcaneal fractures. Clinical orthopaedics and related research. Clin Orthop Relat Res 2000;375:91-96.
15. Hammond AW, Crist BD. Percutaneous treatment of high-risk patients with intra-articular calcaneus fractures: A case series. Injury 2013;44:1483-1485.
16. Abdelgaid SM. Closed reduction and percutaneous cannulated screws fixation of displaced intra-articular calcaneus fractures. Foot and ankle surgery: Official Journal of the European Society of Foot and Ankle Surgeons. 2012;18:164-179.
17. Levine DS, Helfet DL. An introduction to the minimally invasive osteosynthesis of intra-articular calcaneal fractures. Injury 2001;32:51-54.
18. Zhang J, Xiao B, Wu Z. Surgical treatment of calcaneal fractures with bioabsorbable screws. Int Orthop 2011;35:529-33.
19. Loucks C, Buckley R. Bohler's angle: Correlation with outcome in displaced intra-articular calcaneal fractures. Orthop trauma 1999;13:554-558.
20. Chen MY. Boehler's angle: A reappraisal. Ann Emerg Med 1991;20:122-124.
21. Longino D, Buckley RE. Bone graft in the operative treatment of displaced intraarticular cal-caneal fractures: is it helpful? J Orthop trauma 2001;15:280-286.
22. Bakker B, Halm JA, Van Lieshout EM, et al. The fate of Bohler's angle in conserva-tively-treated displaced intra-articular calcaneal fractures. International Orthopaedics 2012;36:2495-2499.
23. Randle JA, Kredler HJ, Stephen D, et al. Should calcaneal fractures be treated surgically? Clin Orthop 2000;377:217-227.
24. Folk JW, Starr AJ, Early JS. Early wound complications of operative treatment of calcaneus fractures: analysis of 190 fractures. J Ortho. Trauma 1999;13:369-372.
25. Strauss EJ, Gabriel-Petrucelli BS. Blisters associated with lower-extremity fracture: Results of a prospective treatment protocol. J Orthop Trauma 2006;20:618-622.