Int J Clin Exp Med 2018;11(10):11169-11176
www.ijcem.com /ISSN:1940-5901/IJCEM0079854

Original Article

Assessment of the curative effects of open reduction and internal fixation with bone grafting on calcaneal displaced intra-articular fractures

Haining Xu*, Jianshu Lu*, Liang Li#, Hongyan Tian#

*Department of Orthopaedics, Dongying People's Hospital, Dongying, Shandong Province, China. *Equal contributors and co-first authors. #Equal contributors and co-second authors.*

Received May 18, 2018; Accepted June 10, 2018; Epub October 15, 2018; Published October 30, 2018

Abstract: Objective: The aim of this study was to compare the curative effects between open reduction and internal fixation with bone grafting and non-surgical treatment of calcaneal displaced intra-articular fractures. Methods: Data concerning 113 patients with closed calcaneal fractures, treated in Dongying People's Hospital from February 2011 to January 2013, were retrospectively analyzed. Specifically, there was complete follow up data for 79 of the patients, in accord with inclusion criteria. Patients were divided into two groups based on different modes of treatment, including 37 cases in the surgical treatment group and 42 cases in the non-surgical treatment group. After treatment, patients were followed up in the clinic and Imaging Department for at least five years, until January 12, 2018. Patient foot function recovery was assessed with ankle hindfoot scores of American Orthopaedic Foot & Ankle Society (AOFAS). Bohler and Gissane angles were measured by reexamining lateral X-ray films of calcaneus. Post-treatment near-term complications (incision infections or necrosis of surrounding skin and plantar fascial compartment syndrome) and long-term complications (subtalar arthritis) were recorded in detail. Results: Differences between the baseline data (sex ratio, age, Sanders typing, Bohler angle, Gissane angle, injury cause, etc.) of the two groups of patients were not statistically significant (all $P>0.05$). One year after treatment and at the time of last follow up, the surgical group's Bohler and Gissane angles were superior to those of the non-surgical group, with statistically significant differences (all $P<0.05$). One year after treatment and at the time of last follow up, AOFAS ankle hindfoot scores of both groups increased compared with those upon admission, with statistically significant differences (all $P<0.05$). Moreover, AOFAS scores of the surgical group were higher than the non-surgical group, with statistically significant differences ($P<0.05$). The surgical group's near-incision infection or necrosis of surrounding skin incidence was 29.73%, while the non-surgical group's plantar fascial compartment syndrome incidence was 7.14%. Differences were statistically significant (both $P<0.05$). At the time of last follow up, the non-surgical group's subtalar arthritis incidence was obviously higher than the surgical group (45.24% vs. 21.62%), with statistically significant differences ($P<0.05$). The surgical group's incision infections or necrosis of surrounding skin underwent anti-infection or flap transposition repair, with all incisions undergoing primary healing. Incidence of plantar fascial compartment syndrome in the non-surgical group was 7.14%. Patient conditions improved after the plantar fasciotomy was carried out, with no significant impact on overall curative effects. Conclusion: Open reduction and internal fixation with bone grafting can restore the smoothness of articular calcaneal surface as well as the height and length of calcaneus. They can prevent the bulging of compacted calcaneus towards both sides, reduce traumatic subtalar arthritis incidence after calcaneal displaced intra-articular fractures, and improve patient foot function.

Keywords: Open reduction and internal fixation, calcaneal intra-articular fractures, subtalar arthritis, complications

Introduction

Calcaneal fractures are clinically common fractures mainly occurring in the young and middle-aged wounded. These patients typically have fallen from a height, with the foot down to the ground, vertically impacted in the heel [1]. The following pathological changes may happen: height loss of calcaneus, especially on the medial wall, width increase of calcaneus, damage to subtalar joint surface, lateral wall prominence, and inverted calcaneal tuberosity. About 75% of calcaneal fractures fall in the category of displaced intra-articular fractures [2].

Calcaneal displaced intra-articular fractures are mainly of the Sanders II and Sanders III type and are mostly caused by a combination of shearing force and compressive force. The positions of fracture lines and numbers of fractured bone fragments are different and damage to different degrees exists on the subtalar joint surfaces. Some articular cartilages may be missing, seriously affecting overall appearance and mechanical stability of the foot [3]. Although surgical treatment can realize anatomical reduction of obviously displaced intra- and extra-articular fractures, in reducing the sequelae during conservative fracture treatment, some patients have been subjected to such complications as delayed union, skin edge necrosis, and incision infections after undergoing surgery. Thus, it remains controversial whether surgical treatment has a more dominant advantage [4, 5]. In the past 20 years, clinicians and patients have paid more attention to the near-term curative effects of therapeutic regimens. Accordingly, relevant reports on medium- and long-term follow ups have been rare [6].

For this research, at least five years of follow up data were retrospectively analyzed. Curative effects of the two methods, calcaneal displaced intra-articular fracture operation and non-surgical treatment, were compared. This study aimed to provide more effective and safe reference materials for formulating clinical regimens.

Materials and methods

Clinical data

Data of 113 patients with closed calcaneal displaced fractures, accepting treatment in Dongying People's Hospital, from February 2011 to January 2013, were retrospectively analyzed.

Inclusion criteria: (1) Closed injury of the calcaneus of one foot; (2) Aged 18- 65 years old; (3) Fracture displacement no less than 2 mm as proven by axial and coronal CT images; and (4) Follow up period of no less than 5 years [7].

Exclusion criteria: (1) Serious subtalar arthritis existing on the affected side before the operation; (2) Old calcaneal fractures; (3) Open injuries; and (4) Incomplete case history or images [8].

Complete follow up data was available for 79 patients. Patients were divided into two groups based on different modes of treatment, including 37 cases in the surgical treatment group and 42 cases in the non-surgical treatment group. Regarding selection of therapeutic regimens, patients agreed on suggested therapeutic regimens and signed informed consent after being informed concerning the advantages and disadvantages of relevant treatment. This research was approved by the Ethics Committee of Dongying People's Hospital.

Methods

After hospitalization, the surgical group accepted bed-rest immobilization, subtalar joint elevation, and local icing with intravenous 20% mannitol injections to reduce swelling in the foot. The operation was arranged after swelling basically disappeared and after positive skin wrinkle test results [9]. Operation dates were all within 14 days after patients were injured. L-shaped incisions were formed on the lateral side of the calcaneus. Longitudinal parts of the incisions originated from 3 to 4 cm above the lateral malleolus and were located between the peroneus brevis and the Achilles's tendon. They were approximated to the position ranging from the outer edge of Achilles's tendon to which was 2.5 cm from the lateral malleolus. The position where the plantar skin and lateral skin intersected was folded into an arched shape and extended forward to the fifth tarsometatarsal joint. The flap was cut open and stripped by closely attaching the scalpel onto the whole cortex of calcaneus. The lateral cortex of broken calcaneus was opened to fully learn the fracture displacement and the calcaneus was pried and restored with periosteum detachers to restore the Gissane angle. A Kirschner needle was threaded at the calcaneal tuberosity and then pulled downwards to restore the Bohler angle. Fluoroscopy was carried out with a C-arm X-ray apparatus to confirm talocalcaneal smoothness as well as the screw direction and length appropriateness. After restoration of the Gissane and Bohler angles, the calcaneal width was restored, as far as possible, by manual squeeze [10]. The autogenic or artificial ilium was filled for patients suffering from bone

Table 1. General data of the two groups

Group	Surgical treatment group	Non-surgical treatment group	$t/X^2/H$	P
Case	37	42		
Gender (male/female)	27/10	31/11	0.080	0.249
Age (years)	50.11±18.92	48.62±16.33	0.377	0.727
Type of Sanders (II/III)	29/8	33/9	0.278	0.186
Injury cause (traffic accident/tumble)	8/29	10/32	0.035	0.957
Bohler angle (°)	17.34±4.75	17.86±4.57	0.267	0.792
Gissane angle (°)	155.08±9.52	154.67±8.83	0.345	0.731

loss of more than 2 cm^3. Afterwards, the anatomic plate was formed per the shape of the lateral surface of the calcaneus and fixed with screws.

The non-surgical group accepted prying with osseous pins and closed manual reduction. This was to restore the collapsed joint surface of calcaneus, Bohler angle, Gissane angle, and normal calcaneal width [11].

Fixation with calcaneus boots or gypsum was adopted for both groups of patients. Patients were advised to rest in the bed and elevate the injured subtalar joint, while simultaneously actively moving the quadriceps, femoris, and toes. Afterward, they exercised the ankle joint and foot function as suggested by inductogram reexamination results.

For infections or necrosis of surrounding skin of incisions, dressing change strengthening or prolonging the time for systemic use of antibiotics was adopted. After dressing change was strengthened, if infections remained difficult to control, the internal fixture was removed. Next, the wound surface was repaired by conducting flap transposition in the locality of shank. Plantar fascial compartment syndrome was treated with plantar fasciotomy.

Post-operative follow up and observational indexes

Follow up periods were no less than five years, ending on January 12, 2018.

Main observational indexes: (1) One year after treatment and at the time of last follow up, patient foot function restoration was assessed with American Orthopaedic Foot & Ankle Society (AOFAS) ankle hindfoot scores [12]; (2) Lateral X-ray films of calcaneus were reexamined to measure Bohler and Gissane angles; (3) Near-term complications (infection or necrosis of surrounding skin of incision and plantar fascial compartment syndrome) and long-term complications (subtalar arthritis) were recorded in detail [13, 14].

Secondary observational indexes: Near-term complication treatment and results of the bacterial culture of samples taken from patients suffering post-operative infections.

Statistical treatment

Two groups of professional medical statistics researchers independently carried out analysis with SPSS 21.0 software. Measurement data, according to normal distribution, are indicated by mean ± standard deviation ($\bar{x}$ ± sd). Additionally, t-tests were carried out. Enumeration data are indicated with rates. X^2 tests and rank sum tests were also adopted. Based on P=0.05, it was judged whether differences between the two groups were statistically significant.

Results

Baseline data

Differences in baseline data of the two groups, including sex ratio, age, Sanders typing, Bohler angle, Gissane angle, and injury cause were of no statistical significance (all P>0.05) as shown in **Table 1**.

Bohler angle and Gissane angle

After treatment, Bohler and Gissane angles were obviously improved compared to time of admission, with statistically significant differences (all P<0.001). One year after treatment and at the time of last follow up, Bohler and

Table 2. Comparison between the Bohler and Gissane angles of patients of the two groups in different stages

Group	Surgical treatment group	Non-surgical treatment group	t	P
Case	37	42		
Bohler angle (°)				
On admission	17.34±4.75	17.86±4.57	0.267	0.792
One year after treatment	38.03±4.63	27.85±5.14	9.080	<0.001
Last follow-up	37.11±3.87	25.52±4.63	10.843	<0.001
t	13.112*/12.032#	10.341*/9.979#		
P	<0.001*/<0.001#	<0.001*/<0.001#		
Gissane angle (°)				
On admission	155.08±9.52	154.67±8.83	0.345	0.567
One year after treatment	129.28±9.66	142.31±8.52	12.149	<0.001
Last follow-up	123.14±6.05	141.85±7.21	22.134	<0.001
t	12.011*/11.124#	7.112*/7.003#		
P	<0.001*/<0.001#	<0.001*/<0.001#		

Note: *Means the comparison between the situation one year after treatment and that on admission; #means the situation at the time of the last follow-up and that on admission.

Table 3. Comparison between AOFAS ankle hindfoot scores of the two groups in all stages

Group	Surgical treatment group	Non-surgical treatment group	t	P
Case	37	42		
On admission	60.23±5.17	59.71±4.86	0.213	0.895
One year after treatment	76.41±15.32	73.54±16.08	3.874	0.017
Last follow-up	81.12±19.65	77.53±16.35	4.394	0.008
t	5.711*/6.213#	5.554*/5.933#		
P	0.002*/<0.001#	0.004*/<0.001#		

Note: AOFAS, American Orthopaedic Foot & Ankle Society; *means the comparison between the situation one year after treatment and that on admission; #means the situation at the time of the last follow-up and that on admission.

Gissane angles of the surgical group were obviously superior to those of the non-surgical group, with statistically significant differences (all P<0.001) as shown in **Table 2**.

Foot function restoration

One year after treatment and at the time of last follow up, AOFAS ankle hindfoot scores of the two groups obviously increased compared to time of admission, with statistically significant differences (all P<0.05). Moreover, AOFAS ankle hindfoot scores of the surgical group were higher than those of the non-surgical group, with statistically significant differences (both P<0.05) as shown in **Table 3**.

Complications

Incidence of infection or necrosis of surrounding skin of incision was 29.73% in the surgical group, mainly including 6 cases of superficial incision inflammation, 2 cases of methicillin-resistant Staphylococcus aureus incision infection (as verified by the bacterial culture), and 3 cases of necrosis of surrounding skin of incision. The incisions were all primary healing throughout anti-infection or flap transposition repair. The non-surgical group's plantar fascial compartment syndrome incidence was 7.14%. Plantar fascial compartment syndrome was relieved after treatment with plantar fasciotomy. During follow up conducted one year after treatment, differences in subtalar arthritis incidence of the two groups were of no statistical significance (P>0.05). At the time of last follow up, subtalar arthritis incidence of the surgical group was obviously lower than the non-surgical group (21.62% vs. 45.24%), with statistically significant differences (X^2=6.221, P<0.05) as shown in **Table 4**.

Table 4. Comparison between the near- and long-term complication incidence (n, %)

Group	Surgical treatment group	Non-surgical treatment group	χ^2	P
Case	37	42		
Near-term complications				
Infection of necrosis of surrounding skin of incision	11 (29.73)	0	21.231	<0.001
Plantar interfacial compartment syndrome	0	3 (7.14)	17.371	<0.001
Long-term complication (subtalar arthritis)				
One year after treatment	7 (18.92)	9 (21.43)	0.127	0.723
Last follow-up	8 (21.62)	19 (45.24)	6.221	0.005

Table 5. Treatment of near-term complications of the two groups (n, %)

Group	Surgical treatment group	Non-surgical treatment group
Case of complications (case)	11	3
Infection of necrosis of surrounding skin of incision		
Cured	11 (100.00)	
Not cured	0	
Plantar interfacial compartment syndrome		
Cured		3 (100.00)
Not cured		0

Treatment of near-term complications

Infection or necrosis of surrounding skin of incision for the surgical group were primarily healed throughout anti-infection or flap transposition repair. For the non-surgical group, patients with plantar fascial compartment syndrome were relieved after receiving plantar fasciotomies, having no significant influence on overall curative effects as shown in **Table 5**.

Discussion

Most calcaneal intra-articular fractures are of the closed type. Yet, patients usually suffer from serious damage to soft tissue, subtalar joint displacement, and loss of calcaneal shape due to the intense traumatic violence. Functional mobility of the lower limbs is highly affected and patients may lose their ability to work, resulting in a heavy burden to the society [15]. For lateral calcaneal joint fractures and calcaneal non-displaced intra-articular fractures, non-surgical treatment is usually adopted [16]. After the 1990s, due to the emergence of CT scanning technology, more clinicians were chose to treat calcaneal displaced intra-articular fractures with open reduction and internal fixation. Open reduction and internal fixation through a lateral L-shaped enlarged incision, the most frequently used surgical method, is beneficial in that the calcaneus restores its normal anatomic form. However, it remains controversial whether it can improve the final prognosis of Sanders type II and III calcaneal displaced fractures.

It has been widely recognized that the appearance of calcaneus, anatomical reduction of joint surface, and reconstruction of Bohler and Gissane angles are important factors affecting calcaneal fracture surgery [17]. Research by Dei et al. on the relevancy between the postoperative 3D morphological features of calcaneal fractures and ankle-hindfoot function has proven that the Bohler and Gissane angles, after a calcaneal fracture, greatly affect the restoration of ankle-hindfoot function [18]. However, Sivakumar et al. assessed ankle joint function with assessment questionnaires, with results indicating that open reduction and internal fixation is generally superior to conservative treatment, but without prominent advantages [19]. During follow up for this present research, it was indicated that, compared with conservative treatment, open reduction and internal fixation can better improve Bohler and Gissane angles. Moreover, the surgical group's AOFAS scores were higher than the non-surgical group, with statistically significant differences ($P<0.05$). Therefore, compared with non-surgical treatment, for treatment of calcaneal dis-

placed intra-articular fractures, anatomical reduction and imaging parameter reconstruction of joint surface realized by an open reduction and internal fixation can well restore the articular calcaneal surface smoothness, restore calcaneus height and length, prevent bulging of compacted calcaneus towards both sides, and realize early-stage postoperative movement. These are of great significance in restoring a normal foot arch and improving ankle joint function.

Currently, when selecting therapeutic regimens, clinicians consider the long-term recovery of foot function and influences on work and life, in addition to near-term curative effects. Research conducted by Niikura et al. indicated that no serious complications would be caused by any standard operation or conservative treatment [20]. Results of this present study indicated that incidence of infection or necrosis of surrounding skin of incision of the surgical group was 29.73%, mainly including 6 cases of superficial incision inflammation, 2 cases of methicillin-resistant Staphylococcus aureus incision infections, and 3 cases of necrosis of surrounding skin of incision. Incisions for the surgical group were all primary healing throughout anti-infection or flap transposition repair, despite high incidence of infection or necrosis of surrounding skin of incision. Plantar fascial compartment syndrome incidence for the non-surgical group was 7.14%. Plantar fascial compartment syndrome was relieved after plantar fasciotomy. Therefore, general curative effects were not significantly affected. Sagray et al. reported that incidence of skin edge necrosis in enlarged lateral access was 24.50% and plantar fascial compartment syndrome incidence was 8.00%. After collection of the curative effects of surgical and conservative treatment of calcaneal displaced fractures, meta-analysis results indicated that complication incidence of the conservative treatment group was obviously higher than the surgical group, with statistically significant differences ($P<0.05$) [21]. There are two main factors causing infections of incised skin. First, surgical timing wasn't correct. Eight hours to 7 days after patient injury, swelling is obvious and closed fractures even have tension blisters, while local soft tissues are subject to hypoimmunity. Skin hurt by surgical incisions can reaggravate, resulting in microvascular occlusion, delayed union, cutaneous necrosis, and infection of incision. Second, calcaneus is a sort of cancellous bone with a rich blood supply. Thus, it may be subject to huge bleeding after undergoing an operation. Infection probability will also increase if post-operative incision drainage is not smooth [22]. A recent study reported that the best surgical time is within 8 hours after injury when no swelling or blisters appear and more than seven days to 2 weeks after injury when swelling has disappeared [23]. Negative pressure closed drainage is an active drainage mode applied in treating ankle trauma. Some research has indicated that negative pressure closed drainage can effectively clear effusion flowing from the wound surface to reduce infection incidence [24]. Differences in subtalar arthritis incidence obtained one year after the operation of the groups was of no statistical significance ($P>0.05$). Yet, at the time of last follow up, the non-surgical group's subtalar arthritis incidence was obviously higher than the surgical group (45.24% vs. 21.62%), with statistically significant differences ($X^2=6.221$, $P<0.05$). Traumatic subtalar arthritis has such clinical symptoms as weight bearing and walking pain, limited movement, and influence on life and work. In addition, another research has proven that calcaneal fracture malunion caused by conservative treatment may result in lack of smoothness of subtalar joint surface, bulging of the lateral calcaneal wall, movement of the fractured segment toward the outwardly upper side, shortening and outward angulation of calcaneal axis, calcaneofibular impact, flat foot arch, heel widening, relative dorsal flexure of ankle bone, tibiotalar impact, upward and forward movement of dead point of Achilles's tendon, calcaneus height reduction, calcaneal compact, and other morphological changes. Secondary operations are required in most circumstances [25].

In conclusion, open reduction and internal fixation with bone grafting can restore smoothness of articular calcaneal surface as well as calcaneus height and length, prevent bulging of compacted calcaneus towards both sides, reduce incidence of traumatic subtalar arthritis after a calcaneal displaced intra-articular fracture, and improve patient foot function. This study had some limitations. This research was retrospective, with lots of various factors affecting the curative effects on both groups. Sample

sizes were relatively small and disease subtypes could not be easily divided in terms of fracture type. Prospective research should be carried out in the future, with increased sample sizes, to further examine the advantages and disadvantages of surgical treatment and conservative treatment.

Disclosure of conflict of interest

None.

Address correspondence to: Haining Xu, Department of Orthopaedics, Dongying People's Hospital, No.317 Nanyi Road, Dongying 257091, Shandong Province, China. Tel: +86-0546-8331577; E-mail: xuhaining996@163.com

References

[1] Sanders R, Vaupel Z, Erdogan M and 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: 551-563.

[2] Backes M, Schepers T, Beerekamp MS, Luitse JS, Goslings JC and Schep NW. Wound infections following open reduction and internal fixation of calcaneal fractures with an extended lateral approach. Int Orthop 2014; 38: 767-773.

[3] Liu WH. Locking plate can prevent the loss of reduction for intra-articular calcaneal fractures. Chinese Journal of Tissue Engineering Research 2017; 15: 2383-2387.

[4] Sampath KV, Marimuthu K, Subramani S, Sharma V, Bera J and 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: 2505-2512.

[5] Wallin KJ, Cozzetto D, Russell L, Hallare DA and 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: 740-743.

[6] Kwon JY, Guss D, Lin DE, Abousayed M, Jeng C, Kang S and Ellington JK. Effect of delay to definitive surgical fixation on wound complications in the treatment of closed, intra-articular calcaneus fractures. Foot Ankle Int 2015; 36: 508-517.

[7] Xu TL, Gu WQ, Li TZ, Zhang HT, Gong ZL, Xu HW, Shi ZM. Application of poly-axial calcaneal locking plate for sanders type IV intra-articular calcaneal fractures. Chinese Journal of Orthopaedics 2016; 21: 1341-1347.

[8] Abdelazeem A, Khedr A, Abousayed M, Seifeldin A and Khaled S. Management of displaced intra-articular calcaneal fractures using the limited open sinus tarsi approach and fixation by screws only technique. Int Orthop 2014; 38: 601-606.

[9] Li Z. Clinical effect of small incision anatomical plate and compression bolts in the treatment of intra-articular calcaneal fractures. Laboratory Medicine and Clinic 2017; 13: 1888-1890.

[10] Yin M, Zang SL, Lu CY. The effect of locking plate on the degree of recovery of Bohler angle and the function of ankle joint in patients with intra-articular fracture of calcaneus. Hebei Medicine 2016; 12: 2024-2025, 2026.

[11] Ren KW, Wei S, Jiang XF, Huang GW, Shen JG. Observation of the clinical efficacy of modified calcaneal plate for the treatment of intra-articular calcaneus fracture. Journal of Shanghai Jiaotong University (Medical Science) 2016; 12: 1768-1771.

[12] Holm JL, Laxson SE and Schuberth JM. Primary Subtalar Joint Arthrodesis for Comminuted Fractures of the Calcaneus. J Foot Ankle Surg 2015; 54: 61-65.

[13] Wang YH, Zou SP, Cheng H, Dong H, Zhu XG. Clinical analysis of poor wound healing after calcaneal fracture. China Practical Medical 2016; 11: 58-59.

[14] Cai GX, Zeng YR, Zeng JC, Xiao ZQ, Zhang XH. Comparison of the curative effect of the tarsal sinus approach and lateral expansion approach in the treatment of intra-articular calcaneal fractures. The Journal of Practical Medicine 2017; 16: 2736-2739.

[15] Herbort M, Domnick C and Petersen W. Arthroscopic treatment of tibial plateau fractures. Oper Orthop Traumatol 2014; 26: 573-588.

[16] Yu T, Yang YF, Li B, Chen K, Zhu H, Zhang MZ, Zhao YG, Yu GR. Open reduction and internal fixation assisted by medial distraction for intraarticular calcaneal fractures. Chinese Journal of Orthopaedic Trauma 2016; 3: 197-202.

[17] Chiu CH, Cheng CY, Tsai MC, Chang SS, Chen AC, Chen YJ and Chan YS. Arthroscopy-assisted reduction of posteromedial tibial plateau fractures with buttress plate and cannulated screw construct. Arthroscopy 2013; 29: 1346-1354.

[18] Dei Giudici L, Di Muzio F, Bottegoni C, Chillemi C and Gigante A. The role of arthroscopy in articular fracture management: the lower limb. Eur J Orthop Surg Traumatol 2015; 25: 807-813.

[19] Sivakumar BS, Wong P, Dick CG, Steer RA and Tetsworth K. Arthroscopic reduction and percutaneous fixation of selected calcaneus fractures: surgical technique and early results. J Orthop Trauma 2014; 28: 569-576.
[20] Niikura T, Sugimoto M, Lee SY, Sakai Y, Nishida K, Kuroda R and Kurosaka M. Tactile surgical navigation system for complex acetabular fracture surgery. Orthopedics 2014; 37: 237-242.
[21] Sagray BA, Stapleton JJ and Zgonis T. Diabetic calcaneal fractures. Clin Podiatr Med Surg 2013; 30: 111-118.
[22] Schuh R, Gruber F, Wanivenhaus A, Hartig N, Windhager R and Trnka HJ. Flexor digitorum longus transfer and medial displacement calcaneal osteotomy for the treatment of stage II posterior tibial tendon dysfunction: kinematic and functional results of fifty-one feet. Int Orthop 2013; 37: 1815-1820.
[23] Wang QX, Zhou YB, Zhao SM, Zhang C, Zhang YZ. Homeopathic closed leverage anatomical plate with compression bolt for treatment of displaced intra-articular calcaneal fractures. Chinese Journal of Trauma 2017; 7: 602-607.
[24] Dickens JF, Kilcoyne KG, Kluk MW, Gordon WT, Shawen SB and Potter BK. Risk factors for infection and amputation following open, combat-related calcaneal fractures. J Bone Joint Surg Am 2013; 95: e24.
[25] Zhang T, Wan CY, Xu WG, Ma BT, Mei XL, Jia P, Yao H. Treatment of displaced intra-articular calcaneal fractures with Orthofix external fixation. Chinese Journal of Orthopaedic Trauma 2016; 12: 1040-1045.