Cell Biochem Biophys (2015) 72:153–156
DOI 10.1007/s12013-014-0427-1

ORIGINAL PAPER

Clinical Analysis of Internal Fixation Treatment of Intra-articular Calcaneal Fractures with Titanium Plate

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Published online: 7 January 2015

Abstract To explore the clinical effect of internal fixation treatment of intra-articular calcaneal fractures with titanium plate, we used open reduction and internal fixation with titanium plate to 48 treated feet from 42 patients with intra-articular calcaneal fractures. The efficacy of surgical treatment was evaluated based on assessment of pain, function, and line of force aspects according to the American Orthopedic Foot and Ankle Society scoring system. Our data show that internal fixation with titanium plate is an effective treatment for calcaneal fractures. It provides satisfactory reduction, reliable fixation, and early rehabilitation.

Keywords Calcaneus · Fracture · Internal fixation

Introduction

Intra-articular calcaneal fractures are the most common tarsal bone fractures, accounting for about 60 % of tarsal bone fractures and 2 % of body fractures. Due to complex anatomical structures around calcaneus and poor coverage of local soft tissue, patients with intra-articular calcaneal fractures are difficult to treat and have more chance to get sequelae and poor prognosis [1]. With the rapid development of internal fixation and imaging technologies, as well as deeper understanding of calcaneal biomechanics and fractures, internal fixation treatment has been wildly accepted [2]. Recent reports show that 90.2–98.3 % of the excellent rates for the treatment of intra-articular calcaneal fractures have been achieved with the application of open reduction and internal fixation with plastic titanium plate [3, 4]. Between March 2005 and September 2011, we treated 48 feet from 42 patients with intra-articular calcaneal fractures by internal fixation with plastic titanium plate. 35 feet from 33 patients were followed up. The data show that the treatment had satisfactory effectiveness.

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Materials and Methods

Patients

48 feet from 42 cases including 27 males and 15 females were studied. There were six patients who had fractures in both feet. Thirty-eight cases were caused by falling injury and four cases were caused by traffic injury. Two patients had preoperative consolidated skin defects, one patient had consolidated fracture of left tibia, and two patients had consolidated L2 vertebral compression fractures. According to Sanders classification, 16 feet had type II fractures, 19 feet had type III fractures, and 13 feet had type IV fractures.

Surgery

Lateral L-shaped incision was initiated at the midline that was about 7 cm above the fibular end and then extended toward the fibular end. The incision was just in front of the calcaneal tendon when it reached fibular end. The incision was then turned 90 ° at heel and extended along the lateral side of the heel until it reached the fifth metatarsus. Next, sharp incision was made in subcutaneous tissue to reach the lateral wall of the calcaneus. Peroneal nerve was carefully protected during surgery. Subperiosteal dissection was performed along the lateral wall. The peroneal tendons and flap were lifted above the articular surface of calcaneus and talus, and Kirschner wires were placed into the upper layer of calcaneocuboid and talar articular surface, respectively. They were bent 90 ° to pull the flap. Periosteum detacher was used to pry the prominent lateral wall to fully expose the subtalar joint. The inner and outer lateral walls were pushed to correct the width of calcaneus and to align the posterior articular surface of calcaneus with articular surface of talus. In order to restore the height of the calcaneus, bone grafting was performed under the anterior articular surface of calcaneus for Sanders III and IV fractures using alloplastic grafts and autologous bones. Alloplastic grafts were used on four feet and autologous bones were used on 27 feet. The reduction of lateral, axial, and Broden positions was verified with X-ray. Plastic titanium plates were used for internal fixation. Wound was then sutured and drainage sheets were placed. Within 48 h after surgery, drainage sheets were removed and patients started ankle exercise. Stitches were removed after 2–3 weeks of surgery and weight-bearing activities were started after 8–12 weeks of surgery.

Surgery Evaluation

The evaluation is based on the assessment of pain, function, and power lines after surgery according to the AOFAS scoring system.

Statistical Analysis

Statistical analysis was performed using SPSS 17.0 software (SPSS Inc.). Paired *t* test was used for analysis of Bohler and Gissane angles, and the AOFAS scores obtained before and after surgery. The α level is 0.05.

Results

35 feet from 33 patients were followed up for 3–28 months, with 17 months on average. All fractures were healed within 8–12 weeks after surgery. There were three patients who had wound infection and plate exposure after surgery. They were treated with wound dressing and healed after 1 month. Conditions such as neurological and vascular injury, fracture displacement and internal fixation failure were not found during and after surgery.

Before surgery, the patients had routine lateral, anteroposterior, and axial positions of foot X-ray examination, as well as coronal and horizontal planes CT scan. Preoperative X-ray and CT scan indicated that the patients had comminuted fractures, dramatic reduction of Bohler angle, and collapse of posterior articular surface of calcaneus. In contrast, the Bohler and Gissane angles, and the height and width of calcaneus were recovered 7 days after surgery (Fig. 1). X-ray showed Bohler angles were improved on average from preoperative $7.31° \pm 1.70°$ to $28.64° \pm 4.25°$ at the seventh day after surgery, and to $31.02° \pm 5.43°$ after 3 months of surgery. Meanwhile, Gissane angles were improved on average from preoperative $162.56° \pm 5.27°$ to $125.63° \pm 12.41°$ at the seventh day of surgery, and to $126.02° \pm 14.07°$ after 3 months of surgery. Bohler and Gissane angles of all 42 cases (48 feet) had statistical significant changes 7 days after surgery. However, when comparing the angles between the seventh day and after 3 months of surgery, there was no statistical significant difference (Table 1), indicating Bohler and Gissane angles were maintained after surgery. We calculated the AOFAS scores for ankles and feet and found that the scores obtained 3 and 6 months after surgery had statistical significant difference comparing with the scores obtained before surgery. While the scores measured 3 and 6 months after surgery do not have statistical significant difference (Table 2). The major discomfort of the follow-up patients is pain after exercise and limited feet movement. The patients were getting better after adjusting the intensity and the way of exercise.

Discussion

Application of Expanded Lateral L-Shaped Incision in Calcaneal Fracture Surgery

Expanded lateral L-shaped incision is suitable for the treatment of 90 % patients who have more than 3-mm shift of posterior articular surface of calcaneus. Although the lateral expansion of L-shaped incision is relatively long and the wound is relatively large, the lateral wall and the structure of the calcaneus, sural nerve, and peroneal tendons are completely exposed. Therefore, the chance of calcaneal damage is relatively low. This approach is the most frequently used since it matches the lateral calcaneal anatomic structure. There are several advantages of this approach. First, it will fully expose the entire lateral wall of the calcaneus, the subtalar posterior articular surface, and the articular surfaces of calcaneus and cuboid bone, which helps surgeons to view and effectively restore bone morphology, and calcaneal and talar joints functions. Second, it creates a larger space at lateral wall of calcaneus for titanium plate. L-shaped incision is able to fully expose the important tissue structures close to bone to reduce the probability of

Fig. 1 **a** The preoperative lateral radiographs of bilateral intra-articular calcaneal fractures show reduced calcaneal height and Bohler angle, and collapsed calcaneal articular surface. **b** The preoperative CT scan images show bilateral comminuted intra-articular calcaneal fractures and increased width of calcaneus. **c** The lateral radiographs of bilateral intra-articular calcaneus after titanium plate fixation show restored calcaneal height and recovered Bohler angle. **d** The postoperative X-ray images of bilateral intra-articular calcaneus after titanium plate fixation show recovered width of calcaneus

Table 1 Comparison of the Bohler and Gissane angles before and after surgery ($\overline{\chi} \pm s$, $n = 35$)

Index	Before surgery	7 days after surgery	3 months after surgery
Bohler angle	7.31° ± 1.70°*	28.64° ± 4.25°**	31.02° ± 5.43°***
Gissane angle	162.56° ± 5.27°#	125.63° ± 12.41°##	126.02° ± 14.07°###

Bohler and Gissane angles were significantly changed after surgery (** vs *, $t = 1.602$, $p = 0.017$; ## vs #, $t = 2.140$, $p = 0.127$; *** vs *, $t = 2.262$, $p = 0.021$; ### vs #, $t = 5.303$, $p = 0.142$). However, the angles measured at day 7 and 3 months after surgery do not have significant difference (** vs ***, $t = 0.235$, $p = 0.513$; ## vs ###, $t = 5.237$, $p = 0.636$)

Table 2 Comparison of AOFAS scores before and after surgery ($\overline{\chi} \pm s$, $n = 35$)

Index	Before surgery	3 months after surgery	6 months after surgery
AOFAS score	16.37 ± 9.21	74.51 ± 5.46	77.63 ± 13.29

AOFAS scores have significant change after surgery ($t = 2.048$, $p = 0.013$; $t = 1.325$, $p = 0.017$) while the scores measured 3 and 6 months after surgery do not have significant difference ($t = 1.711$, $p = 0.815$)

peripheral vascular and nerve damage during surgery, which helps to protect tissues close to the incision. Third, it helps to protect the local blood supply. Flap blood circulation problems are related to a variety of factors, such as the timing of surgery, the choice of surgical approach, and flap separation, etc. We believe surgical approach is an important factor that affects flap blood supply. Use of Kirschner wire for fixation and avoid of electric cautery knife during surgery will reduce the damage to soft tissue and blood supply of the calcaneus during surgery, as well as reduce fat liquefaction and wound infection after surgery. With traditional approaches, the chances that the flap edge does not heal, gets infected, and necrotized are 10–50 %. In this study, 48 feet are treated using modified L-shaped incision. There are only three cases with wound infection after surgery, which are healed with wound dressing after treatment for 1 month.

Timing of Surgery

Timing of surgery has a direct impact on the results. Ideally, open reduction and internal fixation surgery should be performed within 12–24 h after injury. But the patients' soft tissue condition, injury of vital organs, as well as the general condition should also be considered. Since the calcaneus soft tissue has low elasticity and the skin has low blood supply, when fracture happens, bleeding and biomechanics mechanism will lead to increased tension at fracture site and dramatic swelling of soft tissue, which may induce osteofascial compartment syndrome in sever cases. At the same time, surgical wound can cause further damage of soft tissue. Wound suture and healing are more difficult after fracture reduction. Because calcaneal is cancellous and healing is relatively fast, it is relatively difficult for surgery 3 weeks after injury. Yu et al. think that swelling will reach the peak 3 days after calcaneal fracture. Therefore, surgery should be around this time [5]. Tennent et al. think surgery should be performed within 10 days after injury. There are more soft tissue problems if surgery is performed after 14 days and the surgery is less effective [6]. Wound debridement can be applied first if soft tissue condition is poor or when infection is serious in emergency open fractures. Open reduction and internal fixation surgery can be performed within 2–3 weeks after patient condition gets better [7]. We think the ideal surgery time is between 3 and 7 days after injury. If skin blisters form, the surgery can be held to 10th–12th days until the skin of lateral calcaneal folds and has some flexibility. All of our patients were treated with raising injured limbs, applying cold compress, and dehydrating agent. We always use plaster slab for immobilization since plaster clips can cause blisters and rupture. All patients in our study have surgery after their swelling disappear (7–21 days after injury). As a consequence, wound complications are down to 6.25 %.

Advantage of Plastic Titanium Plate

There are many methods and materials for internal fixation [8, 9], including, 1. Special steel plate. 2. U-shaped nails or 2–4 pieces of cancellous bone screws for larger fragment. 3. Tension band. Kirschner and steel wires are used for fixation. 4. Steinmann pin and plaster are used for fixation after prying with Kirschner wire. While there are many methods and materials for fixation, since calcaneal fractures are intra-articular fractures, anatomical reduction is required. At the same time, internal fixation must be strong enough to avoid long-term articular surface collapse, post-traumatic arthritis, and ankle pain.

Researchers found that open reduction is the best choice for Sanders type II and above fractures, and recovery is good after surgery [6, 10]. In our study, anatomical reduction is performed under direct view. Flat surface and calcaneus Bohler and Gissane angles are recovered. We use plastic titanium plate for fixation, which provides good compatibility with multiple holes and points fixation. It has plasticity with screw and good attachment with bone, little stress shielding effect, as well as it works as whole fixation. Therefore, plastic titanium plate is very effective in recovering calcaneus from fragmented pieces.

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