The small dorsolateral incision approach for surgical treatment of Sanders type III intra-articular fractures of the calcaneus

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Abstract: Objective: To investigate the effects of the small dorsolateral incision approach in operative treatment of Sanders type III calcaneal intra-articular fractures. Methods: 90 patients with intra-articular calcaneal fractures of Sanders III type were treated with open reduction and internal fixation through a small dorsolateral incision approach from October 2006 to April 2012. The patients include 69 men and 21 women, aged from 17-61 years with average age 39 years, consist of 49 right calcaneal fractures and 41 left calcaneal fractures. According to Sanders classification, there were 26 type IIIAB fractures, 36 type IIICC and 28 type IIIBC fractures, and all articular surfaces displaced more than 1 mm. The functions of forefoot hindfoot were postoperative evaluated before and after the operation with Ankle and hindfoot score of the American Orthopedic Foot and Ankle Society (AOFAS). Results On average, this group of patients required 4~6 hollow pins (4.0 mm diameter) and 2 full screws (6.5 mm diameter) per patient. 76 patients were followed up for 10 to 56 months (average 20.5 months). All patients showed bony fusion at 8 to 12 weeks (average 9.5 months), no incision infection, skin necrosis, posterior tibial nerve damage, vascular damage or other complications was found. At the time of the latest follow-up, Lateral and axial X-rays of the calcaneus showed good reduction and fixation, and that the length, width, and height of the calcaneus, as well as the Böhler angle and Gissane angle improved after the surgery (P < 0.05). AOFAS ankle/hindfoot scores were 70 to 100 points with the good rate 90.8%, while 45 out of 90 patients were excellent, 24 were good, 5 were acceptable and 2 were poor. There were no incidences of serious complications like the incision infection, nonunion of bones, or osteomyelitis. Conclusion The small dorsolateral incision combined with open reduction and internal fixation can gain good clinical results in treatment of Sanders type III calcaneal intra-articular fractures associated with displacement more than 1 mm.

Keywords: Calcaneus fracture, fracture fixation, internal, bone nails

Introduction

The calcaneus which has a complicated anatomical structure and biomechanical characteristic, also has a complex and diverse fracture morphology. Calcaneal fractures, 60~75% of which involve the subtalar joint, was a very serious injury with 20~30% disability rate, accounts for 2% of all bone fractures and 60% of all tarsal bone fractures [1]. While the calcaneal fractures mainly occur in the peak of adulthood (20~50 years of age), improper treatment may result in severe functional disabilities, patients' incapacity to work, and severe social and economic problems. Currently in China, calcaneal fractures are often treated with open reduction and internal fixation, with 70% excellent and good rate. However, complications with the lateral calcaneal flap are common, occurring in up to 30% cases at small, basic hospitals. There are two main reasons for this: ① Many clinical doctors are not operating carefully and do not paid sufficient attention to protect the soft tissues of the foot during surgery. ② Though the skin of the hindfoot is tough, the soft tissues are very fragile because of poor blood supply. Traumatic intraoperative stretching and clamping may result in skin flap necrosis, infection, delayed or non-healing incision wounds, and even plate exposure in serious cases [2]. Therefore, the small dorsolateral incision approach to surgical treatment of calcaneus...
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fractures has been gaining serious clinical attention. The incision runs parallel to the line connecting the base of the fourth metatarsal to the outside tip of the ankle, located just above the tarsal sinus, for which it was also called tarsal sinus incision. As there are no uniform naming in China yet, this type of incision were unified to small dorsolateral incisions for simplicity in this article. 90 patients with Sanders type III complex intra-articular fractures of the calcaneus from October, 2006 to April, 2012 were treated with internal fixation with hollow tension screws through the small dorsolateral approach, and all achieved satisfactory results, as reported below.

Materials and methods

General Information

90 patients including 69 men and 21 women, aged from 17-61 years with average age 39 years, were selected as subjects of this study. 75 out of 90 patients got fracture because of high falling injury and 15 because of traffic accidents with 49 in right calcaneus and 41 in left calcaneus. All cases were judged Sanders type III including 26 type IIAB, 36 type IIIA, and 28 type IIIBC. The time interval from injury ranged from 5 to 20 days with average time 7.5 days.

Standard preoperative X-ray images were taken for all patients (lateral ankle and axial calcaneus views). After hospital admission, 3D CT reconstructions were performed. All patients have serious fractures involved posterior articular surface, with displacement more than 1 mm, with or without ankle fractures and internal deltoid ligament injuries. Most patients were unable to walk, while some were able to walk into the examination room by themselves with chief complaint of pain around the ankle joint. Calcaneal fractures can be easily missed diagnosis as lack of careful physical examination. Body examination results: petechiae and tenderness of heel lateral, heel medial and planta, widened heel, diminished arch, severe limited eversion and inversion of the foot, crepitus and palpable sense of bone rubbing in the back of the heel.

Preoperative preparation

Detailed medical history especially history of peripheral vascular disease, smoking, diabetes have been were recorded after admission. Take positive measures to control swelling of soft tissue, elevated and immobilized the limb before operation. Perform the surgery after swelling subsides, local skin wrinkles appeared, and the soft tissue condition was stable.

Surgical methods

After general or continuous epidural anesthesia, patient was placed in the lateral position with flexion of the hips and knees. Conventionally, a proximal thigh tourniquet was used. A straight line incision was made from the lateral malleolus to the base of the fourth metatarsal. Dissect the subcutaneous tissues carefully, identify sural nerve, peroneal tendon and calcaneofibular ligament and retracted them downwards. Expose the extensor digitorum brevis tendon, separate part of the extensor digitorum brevis, which would be retracted to the distal of the incision for exposure of the subtalar joint cavity (If the fracture line extended to the anterior process of the calcaneus, then insertion of the muscle was incised to expose the calcaneocuboid articular surface). Clean up the blood clots and soft tissue, wash the incision, and then the subtalar joint cavity should be clearly visible. Several bone fragment of posterior articular surface were displaced and collapsed. Pried them loose one by one from the medial to lateral, then checked the remaining calcaneal fractures before reducing the bone fragments. Calcaneocuboid articular surface was usually displaced, but remained intact after calcaneal fractures. Most of them collapsed, but may defected in a few of serious fracture. Even the articular surface was shattered, it remained intact. As soon as the fracture was reduced, defects would occur in the cancellous tissue in the core of the calcaneus. The better the bone was reduced, the bigger the defects would be. Fewer defects indicated that the fracture was not properly reduced. These types of core defects do not usually require grafts, but grafts are acceptable for large defects.

After inspection, Assistant 1 retract the calcaneal tuberosity downward and backward with Steinmann pins which drilled into the calcaneus, Assistant 1 hold on the lower leg and retract the forefoot forward by hands. While the assistants provided full traction in all three directions, the main surgeon pried the collapsed fragments of the posterior articular surface
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through small dorsolateral incision with traction from inside to outside, from front to back. Temporarily fixate the calcaneal thalamus with Kirschner pins as soon as the reduction was satisfactory, stabilize the posterior articular surface, squeezed the fractured bones of the lateral wall by hand, stretch the posterior tuberosity with Steinmann pins to make sure the calcaneus in the right position from a varus or valgus position, fixate posterolateral and anterointernal bones, anterolateral and anterointernal bones quickly with guiding pins, drilled in the Guiding pins from both sides of the Achilles tendon to the anterior part of the calcaneus and under the surface of the subtalar joint, respectively, along the long axis of the calcaneus. A C-arm X-ray was used to check the reduction of the calcaneus. The above procedure was repeated as needed until satisfactory reduction of the fractured bones was achieved. Hollow tension screws of appropriate length followed the guide pins, effectively reaming out bigger holes. Be careful not to overpress in case of compression deformation of the width and length of the calcaneus. Another intraoperative C-arm X-ray ensured that screws haven’t entered the subtalar cavity or broken through the internal wall. The screw along the long axis of the calcaneus should be the full thread screw with 6.5 mm diameter. The screw should reach cortical bone of the anterior part of the calcaneus and the surface of the subtalar joint, too short (reach the porotic bones in middle of calcaneus) or too long (break through the surface of the subtalar joint and damage the cartilage there) were not suitable. The hollow tension screws with smaller diameter (3.5~4.5 mm) were used to fixate the subtalar articular facet. They arranged in parallel under the subtalar articular surface, strongly fixating the displaced bone fragment of posterior articular surface. The screw should reach solid bone of the sustentaculum tali, too long or under the sustentaculum tali might damage the posterior tibial vessels, nerve, and tendon in the tarsal tunnel. After fixation, another set of lateral and axial C-arm X-ray images of the calcaneus was performed to check reduction of the fracture and the internal fixation condition. Cleaned all bone fragments out of the articular cavity, washed the incision, place the drainage tube routinely, and then closed the incision layer by layer, and wrapped in a compressive bandage.

Postoperative treatment

Forbid the patients and people around to smoke. Fixed the foot in the functional dorsiflexion position with a brace for 2~4 weeks. Antibiotics were used routinely within 24 hours. Remove the drainage tube till the volume was less than 10 ml per day. The patients were encouraged to exercise the toe joint and ankle joint on 3th day to reduce stiffness of the subtalar joint. Every other week after surgery, lateral and axial X-rays of the calcaneus were taken. If the X-ray image showed that the fracture line in the sustentaculum tali had disappeared, and there was continuous trabecular bone across the fracture line, then progressive loading exercises might be started. Hot compress and other physical therapy were used to promote rehabilitation if the patient still had pain or other discomfort.

Efficacy evaluation

Postoperative efficacy were evaluated with Ankle and hindfoot score of the American Orthopedic Foot and Ankle Society (AOFAS). This evaluation score was based on three criteria: pain, function, and alignment. A full score was 100 points. Excellent was 90~100 points. Good was 80~89 points. Acceptable was 70~79 points. Poor was less than 70 points.

Statistical analysis

Statistical analyses were performed using the SPSS software (version10.0). Preoperative and postoperative measurement data were compared using the paired t test. P values < 0.05 were considered statistically significant. P values < 0.05 were considered strong statistically significant.

Results

On average, this group of patients required 4~6 hollow pins (4.0 mm diameter) and 2 full screws (6.5 mm diameter) per patient. 76 patients were followed up for 10 to 56 months (average 20.5 months). All patients showed bony fusion at 8 to 12 weeks (average 9.5 months), no incision infection, skin necrosis, posterior tibial nerve damage, vascular damage or other complications was found. When they walk again, 10 patients presented with transient mild pain
which relieved after hot compress treatment and oral administration of NSAIDs. 8 patients presented with moderate stiffness of hindfoot, which improved after physiotherapy. All patients restored to the previous working position and have no special requirements for shoes and ground surface. 45 patients didn’t remove the internal fixation screws without any symptoms. 31 patients who were young removed the internal fixation screws at 10 to 15 months after their request, and the wounds recovered well.

At the time of the latest follow-up, Lateral and axial X-rays of the calcaneus showed good reduction and fixation, and that the length, width, and height of the calcaneus, as well as the Böhler angle and Gissane angle improved after the surgery (P < 0.05, Table 1). AOFAS ankle/hindfoot scores were 70 to 100 points with the good rate 90.8%, while 45 out of 90 patients were excellent, 24 were good, 5 were acceptable and 2 were poor. There were no incidences of serious complications like the incision infection, nonunion of bones, or osteomyelitis. Typical cases were showed in Figures 1-3.

Discussion

History of calcaneal fracture treatment and advantages/disadvantages of the conventional surgical approach

Calcaneal fractures not involving the posterior facet, or fractures without displacement of the articular surface can be treated conservatively with good prognosis. For intraarticular calcaneal fracture with displacement and some extra-articular fracture, conservative treatment could not restore the calcaneal form, the heel axis, and the smoothness of the articular surface, result in malunion, collapse of the arch, abnormal force line of the hindfoot, ankylosis, collision between the fibula and calcaneus bones, traumatic arthritis, serious decline of the walking function, and even physical disability. Open reduction and internal fixation can achieve good reduction and strong fixation, better recovery of the normal shape and biomechanical properties of the calcaneus, have a better excellent and good rates in clinical efficacy than the conservative treatment [3].

Calcaneal surgery can easily lead to skin complications such as marginal necrosis or infection of the incision wound. However, due to its excellent prognosis, open reduction and internal fixation has already become the standard method to treat displaced intra-articular fractures of the calcaneus. A great deal of clinical researches [4] showed that the ratio of good/excellent results of open reduction and internal fixation surgery is over 75%. Based on biomechanical and clinical researches [5], it is necessary to restore the overall appearance, length, width, height, Böhler angle, and Gissane angle parameters of the calcaneus during reduction of calcaneal fractures. It is also necessary to restore the smoothness of the subtalar articular facet, the normal anatomic relationships at the three articular surfaces, and the weight-bearing axis of the hindfoot. The fixation method should be stable and reliable, allowing early physical training. Therefore, as long as there are no systemic or local contraindications, severely displaced extra-articular fractures and stepped intra-articular fractures should all be treated with surgery.

The treatment of displaced intra-articular fractures of the calcaneus remains controversial. Currently, the Sanders classification scheme is the most widely used typing method for calcaneal fractures. For Sanders type II and III fractures of the calcaneus, open reduction and internal fixation surgery (ORIF) is clearly superior to conservative treatment. For Sanders IV, though it remains unclear whether ORIF is better than conservative treatment, the studies have demonstrated that surgery can restore the external shape of the calcaneus, reduce the incidence of most complications, make secondary surgery easier.

There are four main surgical approaches to treat calcaneus fractures: the extensile lateral L-shaped incision approach, the small dorsolateral incision approach, the internal approach,

<table>
<thead>
<tr>
<th>Time</th>
<th>Length (mm)</th>
<th>Width (mm)</th>
<th>Height (mm)</th>
<th>Böhler angle (*)</th>
<th>Gissane angle (*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preoperative</td>
<td>69.0±3.5</td>
<td>40.2±2.9</td>
<td>47.2±1.9</td>
<td>16.4±5.4</td>
<td>95.1±10.2</td>
</tr>
<tr>
<td>Last follow-up</td>
<td>73.3±2.9</td>
<td>33.3±1.7</td>
<td>49.3±2.4</td>
<td>25.3±3.3</td>
<td>122.1±6.1</td>
</tr>
<tr>
<td>P value &lt; 0.01</td>
<td>0.000</td>
<td>0.000</td>
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</tr>
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</table>
Small dorsolateral incision approach and the sustentaculum tali approach. Though the internal approach can expose the internal wall of the calcaneus very well, it cannot expose of the posterior articular facet, and may damage blood vessels and nerve bundles on the inside of the hindfoot. As the incision of the sustentaculum tali approach is comparatively small [6], and it is only used for simple fractures.

Figure 1. Male patient, 41 years old. Fell from height injury to left calcaneus. Sanders type III fracture. Preoperative lateral ankle X-ray (A); axial X-ray (B); oblique forefoot X-ray (C); Preoperative CT (D-G); Intraoperative hollow screw reduction and fixation X-ray photo (H, I); External photo taken 4 months after surgery (J, K).
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of the sustentaculum tali or as an auxiliary method in the small dorsolateral approach for complex intra-articular fractures associated with sustentaculum tali fracture or fractures of the internal articular facet. Currently, the most widely used approach is the extensile L-shaped incision approach. It allows direct exposure and reconstruction of the entire lateral calcaneal wall, the posterior surface of the subtalar joint, and the calcaneocuboid articulation. This approach is suitable for over 90% of intra-articular calcaneal fracture involving the posterior articular facet [7]. Its advantages were significant as well as the disadvantages. Incidence of incision complications of the surgery performed by inexperienced surgeons or at primary hospitals was up to 30%. Other disadvantages of the extensile lateral L-shaped approach include the following: ① Exposure of the articular surface is not ideal. ② Soft tissues are retracted for long periods of time. This can lead to ischemia and damage to the sural nerve. ③ There is some unavoidable skin necrosis at the corner during the wound healing period. ④ Extensive devascularization can cause ischemia of the lateral wall of the calcaneus. ⑤ The same risks are present again during extraction of fixation plates. ⑥ Some patients experience severe traumatic arthritis. This incision is not the best choice for subtalar arthrodesis surgery.

The ideal pathway was the incision which makes the displaced articular surface clearly visible for convenient reduction of the fracture, offers sufficient space for fixation, and reduces the damage to soft tissue. Therefore, the surgeons are developing a preference for the small dorsolateral incision approach. Its advantages are: ① The subtalar joint surface is directly exposed for convenient reduction. ② The use of hollow tension screws makes internal fixation materials simple. ③ There is little damage to soft tissue. There is no risk of skin flap necrosis because lateral skin flap is not required during the surgery. ④ It will not irritate the sheath of the peroneal tendon and the cutaneous nerves of the sural nerve. ⑤ It does not affect blood supply to the lateral wall of the calcaneus by avoiding the injury of the lateral calcaneal arteries. ⑥ Postoperative management of the incision wound is simple, and the wound heals quickly. ⑦ A skin flap is not required in the secondary surgery during plate extraction. Compared to the extensile lateral L-shaped incision approach, the small dorsolateral incision approach greatly decreases the risks associated with the incision wound, could avoid the occurrence of the skin flap necrosis, metal plate exposure. However, this approach also has obvious drawbacks, including lack of exposure of the lateral wall of the calcaneus, and higher requirements on the installation of fixation materials, which require the surgeon to have more clinical experiences and better surgical skills. However, these disadvantages can be overcome with proper screening of patients and intensified clinical training for surgeons.
Biomechanical characteristics of calcaneal fractures and indications for the small dorsolateral incision approach

Displaced intra-articular calcaneal fractures result from high-energy injuries, happen frequently to patients with high falling injury, during which the weight concentrates on the ankle and cause the fracture. The position of the foot during the injury, magnitude of the force, and osseous condition are all important factors determining the degree of bone comminution and the location of the fracture lines. Although the exact mechanisms of injury are still in dispute, the mechanisms described by Essex-Lopresti [8] and Carr [9] et al. are basically the same. Essex-Lopresti believed that the first fracture line begins where the outer edge of the talus impacts the lateral calcaneus, and then extends inward [8].

In a fall, the posterior subtalar joint is immediately forced into eversion, and the sharp outer taloid spur is driven like an axe into the Gissane angle, splitting it and the outer wall of the bone along its grain. The remainder of the force then descends through the anterior subtalar on to the sustentaculum tali, which may be sheared off the inner side of the body together and with the medial one-third or one-half of the posterior subtalar surface. If the force continues, it can cause fracture lines extending all the way to the leading edge of the calcaneus or even to the calcaneocuboid articulation causing anterolateral bone fragmentation. If the foot falls horizontally, and the force is directed to the hindfoot, the fracture line will extend rearward and upward, extending to the posterior articular surface, causing posterior intra-articular bone fragmentation and downward collapse of the foot. Carr [9] et al. produced the experimental calcaneus fractures by axially loading 18 amputated lower limb specimens, make two constant primary fracture lines with varied loads on the tibia. One type of fracture line split the calcaneus into internal and lateral parts, roughly parallel to the sagittal plane, while the other type extended inward from the vertex of the Gissane angle, splitting the calcaneus into anterior and posterior parts, roughly in the coronal plane. The lateral fracture line proceeded downward, pointing to the plantar surface or forward. These two types of fractures jointly form various tongue-shaped fractures or articular compression type fractures, and anterolateral, posterolateral, and anterointernal bone fragments.

After fully understanding the biomechanical fracture mechanisms described above, we know that calcaneal fracture usually result in anterolateral, anterointernal (sustentaculum tali portion), and posterolateral fragments. On this basis, the subtalar articular surface may be fragmented into lateral, central, and internal parts in the vertical plane, and collapse downward. Reviewing the CT scans of the patients in this study with the standard as mentioned, we can conclude that comminuted calcaneal fractures are not contraindications for the use of the small dorsolateral incision approach, which is also suitable as long as the comminuted fractures are coincide with the biomechanical mechanisms described above. Specific criteria include the following: anterior calcaneus is comminuted but uncompressed form an anterolateral fragment. The internal portion must be relatively intact. It would be better if the part of internal wall attaching to the sustentaculum was intact, because it offers the possibilities for screw fixation. The posterior subtalar articular surface fracture line permits 2~4 screws, but each bone fragment should be relatively large and collapsed wholly, so the fragments can be fixated with screws. The posterior calcaneal tuberosity was complete, only the thalamus was collapsed and comminuted. The Achilles tendon insertion was intact, and there is no upturn tongue-shaped fragment. There was a bulge on the lateral wall. The bottom of the foot was relatively intact. In summary, as long as the calcaneal fractures are consistent with the characteristics described above, a trained surgeon can treat Sanders type III complex intra-articular calcaneal fractures with the small dorsolateral incision approach combined with hollow tension screws.

Surgical skills

According to biomechanical characteristics of these fractures, two types of screws (thin and
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thin screws) could be used for fixation. As for collapsed subtalar joint surface, the fracture line in the sagittal plane and the bone fragments break into lateral, central, and internal parts and collapse downward. The subtalar joint becomes open as the assistant puts forward, backward, and downward traction on the calcaneal body, and then the primary surgeon can then reduce the posterior subtalar articular surface by lightly poking upward. Special attention should be paid for the reduction of the anterointernal bone fragments, which are the only reference for reduction of the lateral fragments. After all fractured bone fragments have been reduced, screw in 1~2 hollow tension screws with diameter of 3.5~4.0 mm from outside to inside, parallel to the subtalar articular surface. This will strongly fixate the fragmented bones of the subtalar articular surface.

We used big diameter hollow tension screws to fixate the three main parts of the body of the calcaneus, the anteriolateral, anterointernal (the sustentaculum portion), and the posteriolateral parts. After intraoperative traction assistance to lever and reduce the bones; ① The screws (4.5 mm) were screwed from anterior side of the calcaneous towards the internal sustentaculum tali to fixate the anteriolateral and internal bone fragments. ② The screws (4.5 mm) were screwed posteriolateral side of the calcaneous towards the internal sustentaculum tali to fixate the posteriolateral and internal bone fragments. ③ The screws (6.5 mm) were screwed from the Achilles tendon of the posterior calcaneal tubercle back to front along the long axis of the calcaneus to fixate the calcaneal body. While maintain full traction lever to restore the height of the calcaneal thalamus, squeeze the bulge of the lateral wall to restore the width, while correct the alignment of the calcaneal tubercle. Through the above process, the calcaneal body anteriolateral, anterointernal, and posteriolateral portions were firmly fixated.

In addition, clean all bone fragments out of the articular cavity and check whether the screws have entered the subtalar articular cavity and broken through the internal wall before closing the incision.

In summary, Though the skin of the hindfoot is tough, the soft tissues are very fragile because of poor blood supply. Extensile lateral L-shaped incision method requires operating in an ischemic region, with large incision wound. Intraoperative stretching, clamping, folding of the skin flap may result in skin flap necrosis, infection, and even plate exposure. Small dorsolateral incision combined with hollow tension screw internal fixation surgery is a good way to avoid these disadvantages. Through training and a good understanding of the indications for this type of surgery, it is definitely possible to achieve the same clinical effect as with extensile L-shaped incisions using steel pins for internal fixation of the calcaneus. Even for rather complex Sanders III type calcaneal fractures, it not only can achieve excellent results, but also completely avoid the occurrence of postoperative complications from a weakened lateral skin flap. Although high loss rate in this group and short follow-up time, the follow-up results have showed that small dorsolateral incision combined with hollow tension screw internal fixation treatment for Sanders III type calcaneal fractures can achieve satisfactory results for both patients and doctors.

Disclosure of conflict of interest

None.

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