



Calcaneal fracture: results of earlier rehabilitation after open reduction and internal fixation

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Abstract

Introduction This study aimed to analyze the clinical and radiological outcomes of early weight-bearing and rehabilitation after open reduction and internal fixation (OR/IF) of calcaneal fracture.

Materials and methods This retrospective study was conducted on 78 patients with unilateral calcaneal fracture who underwent OR/IF. A mean follow-up period was 45.8 months (range 12–135). Two weeks after surgery, the range of motion (ROM) exercise was started, brace or heel off shoe was applied, and forefoot weight-bearing was allowed. Four weeks after surgery, tolerable weight-bearing ambulation without crutch was allowed. When the patient was not walking, the braces were removed to perform peritalar ROM exercises. Radiologic evaluation was performed by measuring the Böhler angle and incongruency of the subtalar joint surface. Paley grade was used to assess traumatic arthritis. Clinical evaluation was performed by measuring the foot and ankle outcome score (FAOS) and ankle ROM.

Results The mean postoperative Böhler angle was 31.7° ($P < 0.001$) at 2 weeks, 31.2° at 3 months, and 30.1° at the last ($P = 0.4$). The average Paley grade of the subtalar OA was 1.12. CT imaging revealed that the average step-off of the subtalar joint was 1.26 mm in coronal and 0.84 mm in sagittal. The average ROM results were as follows (contralateral, affected side): there was no significant difference in dorsiflexion [16.9° vs. 16° ($P = 0.6$)], whereas plantarflexion and inversion were significantly decreased [39.5° vs. 35.3° ($P = 0.049$) and 50.5° vs. 34.8° ($P = 0.04$)]. The average FAOS score was 86.1 points, and the highest score was “function” (mean 92.5 points).

Conclusions Earlier rehabilitation after OR/IF is recommended for the treatment of calcaneal fracture.

Keywords Calcaneal fracture · Earlier rehabilitation · Open reduction and internal fixation · Subtalar joint

Introduction

The calcaneus is a complex bone that acts as a major platform for ambulation and standing and also as a fulcrum that allows the calf musculature to propel the body forward [1, 2]. Compared with other lower limb fractures, rehabilitation for calcaneal fractures tends to be delayed, which has been associated with many controversial issues. Many researchers

recommend the avoidance of weight-bearing for 3 months after calcaneal fracture surgery, because of the potential risk of articular surface collapse during ambulation [3, 4].

However, with increase in the importance of early rehabilitation and functional treatment of the lower extremity, recent studies have reported on advanced timing of weight-bearing after calcaneal fracture surgery, with good clinical outcomes [5, 6].

The purpose of this study was to analyze and report the clinical and radiological outcomes of early weight-bearing and rehabilitation after open reduction and internal fixation (OR/IF) of calcaneal fractures.

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Materials and methods

Materials

This retrospective study was conducted on 78 patients with unilateral calcaneal fractures who underwent open reduction and internal fixation from 2007 to 2016. Exclusion criteria included patients who were managed conservatively, those with concomitant fractures, those with pathologic fractures, those with sinus tarsi approach, and those who received primary arthrodesis in severe comminuted sanders type IV fractures, as these factors may affect the rehabilitation process. Participants included 61 men and 17 women, with a mean age of 54 years (range 21–81 years) and a mean follow-up period of 45.8 months (range 12–135 months). Sixty-one patients were injured by a fall down. The mean time from injury to undergoing surgery was 7.9 days. According to Sander's type classification based on CT evaluation [7], patients were divided as follows: type IIa: 9, type IIIab: 38, type IIIbc: 13, and type IV: 18. There were no cases of type I or IIb fractures. Implant removal with arthrolysis of the subtalar joint was performed at a mean duration of 11.9 months after the initial surgery.

Operative procedures

OR/IF was performed using the extensile lateral approach. The patient was placed in the lateral position under either general or spinal anesthesia. After aseptic draping, the pneumatic tourniquet pressure was inflated to 300 mmHg. A round curved L-shape incision was applied from the lateral side of the Achilles and midway of the posterior border to the fifth MT base. During incision, subperiosteal dissection was carefully performed to avoid injury to the sural nerve, peroneal tendon, and overlying skin. After subtalar joint exposure, soft tissue traction was maintained by inserting two to three k-wires into the talus or fibula to secure the operative field. Subsequently, visualization of the entire posterior facet of the calcaneus was possible. To reduce fracture fragments, the depressed fragments were elevated for the restoration of the articular surface of the posterior facet with direct visualization of the articular surface [8]. With anatomical reduction of posterior facet fragment, lag screw fixation of the sustentacular fragment was performed. After reduction of the sustentacular fragment, 5–10 cc of allo-chip-bone graft was packed into the cancellous bone defect site. The anterior and posterior fragments were fixed with plate and screws.

After confirming bony union on CT scans, implant removal was performed after an average duration of

11.8 months after initial fixation. The fibrotic scar tissue surrounding the subtalar joint was released during the implant removal, because fibrosis of the subtalar joint was observed in all cases. The subtalar joint motion was monitored. The patient was encouraged to initiate vigorous ROM exercises immediately after implant removal and arthrolysis.

Postoperative rehabilitation

Ambulation

A short leg splint was applied and non-weight-bearing was maintained for 2 weeks postoperatively. After 2 weeks, forefoot walking with removable brace or heel off shoe was allowed (Fig. 1). Crutches were used for up to 4 weeks postoperatively for adaptation to forefoot weight-bearing using brace or heel off shoe. After that, tolerable weight-bearing ambulation without crutches was allowed. After 8 weeks, natural ambulation was attempted with a silicone heel pad applied onto an ordinary shoe.

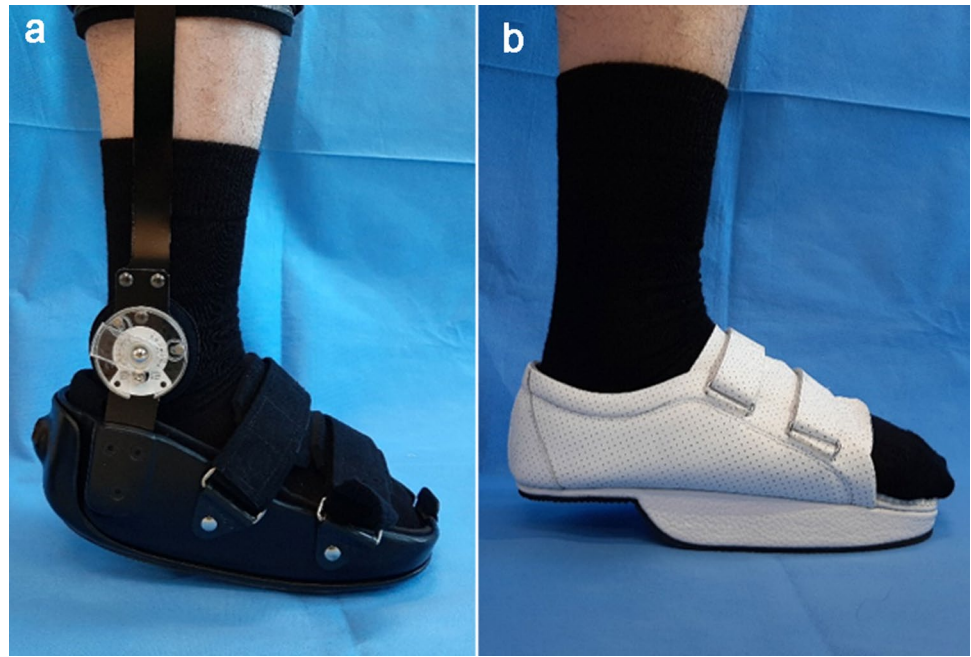
Joint range of motion (ROM) exercise

Active and passive toe stretching was performed immediately after surgery to prevent toe contracture. Subtalar and ankle joint ROM exercises were started after removing stitches at 2 weeks. The "Circle draw exercise" was performed when not ambulating out of brace as open as possible to minimize the stiffness. This exercise was performed with the patient sitting on a bed or chair with suspended legs, so that the knees are flexed to 90° and the ankles are in the neutral position. The patient actively moves the foot in as large a circle as possible [8]. After 8 weeks, the patient is instructed to kneel on their knees for maximum ankle plantar flexion stretching and also perform heel cord stretching exercises for ankle dorsiflexion.

Muscle strengthening exercise

After 2 weeks postoperatively, resistive strengthening exercise of the periankle muscles was performed using Thera-band in four directions: dorsiflexion, plantar flexion, inversion, and eversion. After 4 weeks, calf muscle strengthening exercise was initiated, with the heel raised up and forefoot on the floor while sitting on a chair. Additional exercise to strengthen the proximal and periankle muscles was performed. Knee extension was performed with the band placed on the ankle, sitting on a chair, whereas knee flexion exercise was performed in a prone position. In addition, to strengthen the thigh muscles, the patient was instructed to lie down and perform hip exercise in four directions: flexion, extension,

Fig. 1 **a** A walking brace designed for midfoot weight-bearing without heel contact, which also limited dorsiflexion and allowed plantar flexion with a round bottom sole. **b** A custom-made specialized shoe, which did not contain a sole on the heel, allowing for heel loading off by midfoot weight-bearing



adduction, and abduction. Encouraged heel raising exercise was commenced after 8 weeks.

Brace or heel off shoe

Plantar flexion was allowed to facilitate ankle ROM. A walking brace designed for midfoot weight-bearing without heel contact, which limited dorsiflexion and allowed plantar flexion, with a round bottom sole was initially used. This was later replaced by a custom-made specialized shoe, which did not contain a sole on the heel, allowing for heel loading off by midfoot weight-bearing (Fig. 1). The first 25 patients used braces, whereas the subsequent 53 used custom shoes due to the inconvenience of the brace.

Radiologic assessment

The Böhler angles assessed on the ankle lateral radiograph were compared preoperatively, at postop 2 weeks, 3 months, and at the final follow-up. Heel valgus and varus were evaluated in the hind foot view at the final follow-up. Paley grade was used to determine the presence of subtalar osteoarthritis on standing ankle lateral view at the final follow-up. Subtalar osteoarthritis grading was performed as follows: grade 0: normal joint space, without evidence of degenerative cysts or subchondral sclerosis; grade 1: subchondral sclerosis, osteophytes, and cyst formation, without joint space narrowing; grade 2: joint space narrowing, with sclerosis and cyst formation; and grade 3: complete loss of the joint space [9, 10]. We defined post-traumatic osteoarthritis of the subtalar joint as Paley grade 2 or 3. CT imaging was

performed pre- and postoperatively (after a mean duration of 11.8 months) to measure the articular step-off of the subtalar joint in the coronal and sagittal views [11]. Bony spur or bump of calcaneus and bone union were evaluated also on the CT assessment.

Physical assessment

Dorsiflexion, plantar flexion, and inversion range of motion of the affected side were compared with those of the unaffected side. For evaluation of inversion ROM, the modified McBride method was used [12]. Single-leg standing and single-heel-rise ability were evaluated at the final follow-up.

Functional assessment

The foot and ankle score (FAOS) survey was conducted, and postoperative improvements of the subjective symptoms were evaluated at the final follow-up.

Complications

Complications of wound problems, nerve injury, toe deformity, and non-union were evaluated.

Statistical analysis

The normality of the variables was tested using the Shapiro–Wilk test, and paired *t* test and Wilcoxon signed rank test were performed. The significance level was verified at $P < 0.05$ and $P < 0.001$. One-way ANOVA was used

to compare differences in the Böhler angles at 2 weeks, 3 months, and the final follow-up postoperatively between the groups. Collected data were analyzed using the Statistical Package for Social Science statistics 21 program.

Results

Radiologic evaluation

The preoperative Böhler angle on X-ray ankle lateral view was 7.2° (range –32° to 29°), which significantly improved to 31.7° (range 16°–47°) ($P < 0.001$) at 2 weeks postoperatively. The angle at 3 months postoperatively and at the final follow-up was 31.2° (range 11°–46°) and 30.1° (range 11°–48°) ($P = 0.4$), respectively, showing no significant change over time. The mean step-off of the subtalar joint, assessed on CT, was 1.26 mm (range 0–4.57 mm) and 0.84 mm (range 0–3.86 mm) in the coronal and sagittal views, respectively, at a mean duration of 11.9 months (range 8–19 months) postoperatively. In the hind foot view radiograph, 73 patients had normal alignment, 3 had mild varus, and 2 had mild valgus deformity, all within 10°, indicating that correction was not necessary. Subtalar joint space narrowing was not evident in 55 patients (70.5%). While 23 cases (29.5%) were Paley grade 2, which indicated joint space narrowing, there were no cases of Paley grade 3. A higher incidence of subtalar arthritis was found in patients with Sander's type IV fracture (Table 1).

Clinical evaluation

No significant difference was found in dorsiflexion between the unaffected and affected sides at the final follow-up [16.9° (range 5°–20°) vs. 16° (range 5°–20°)]. In contrast, significant differences were found in plantar flexion [39.5° (range 20°–40°) vs. 35.3° (range 15°–40°); $P = 0.049$] and inversion [50.5° (range 20°–80°) vs. 34.8° (range 20°–60°); $P = 0.04$] of the unaffected and affected sides. Single-leg standing was possible in all patients, but single-heel rise was not possible in seven patients, most of whom were

aged > 60 years. For the evaluation of the FAOS score, comprehensive evaluation of the five categories of pain, symptoms, function, sports, and quality of life was performed. The mean score was 86.1 points (range 52.1–100). The item with the highest score was function [mean 92.5 (range 42.6–100)], and that with the lowest score was sports [mean 77.5 (range 0–100)] (Table 2). In addition, the patient-reported satisfaction improved by 56.3% after implant removal and arthrolysis. Minor wound problems were found in seven patients, which improved after conservative treatment. There were no cases that required reoperation, except for implant removal. No patient presented with toe deformity or non-union, and none needed subtalar fusion.

Discussion

Calcaneal fractures are high-energy injuries with intra-articular fractures that involve the majority of subtalar joints. Anatomical reduction is essential, and joint movement should be restored postoperatively. However, because the calcaneus is positioned to absorb the body weight [8], the weight-bearing and rehabilitation period are delayed in this fracture compared to that in other lower extremity fractures. Ambulation in calcaneal fractures is allowed very cautiously because the majority of researchers recommend partial weight-bearing for 6 weeks postoperatively, and 55% of the available protocols recommend only half weight-bearing after 6 weeks postoperatively [13].

Recent studies have encouraged early mobilization, with partial weight-bearing during the first 6 weeks [14, 15] or 12 weeks [16] postoperatively and for 12 weeks in conservatively treated patients [16, 17]. In a study including 424 patients with displaced intra-articular calcaneal fractures, Buckley et al. recommended 6 weeks of non-weight-bearing after physical therapy and progressive weight-bearing for both surgically and non-surgically managed fractures [5]. Hyer et al. allowed progressive weight-bearing in a walking boot after a mean duration of 4.8 weeks postoperatively. The mean Böhler angle was 30.1° at the first postoperative

Table 1 Numbers of patients with subtalar arthritis according to Sander's classification

Paley grade	Sander's type on the preoperative CT (cases)				Total (%)
	IIa	IIIab	IIIbc	IV	
G0	6	9	3	0	18 (23.1%)
G1	2	21	8	6	37 (47.4%)
G2	1	8	2	12	23 (29.5%)
G3	0	0	0	0	0 (0%)

Table 2 Foot and ankle outcome score (FAOS) after surgery for calcaneal fracture

Category	Score (range)
Average	86.1 (52.1–100)
Pain	90 (44.4–100)
Symptom and stiffness	92.3 (57.1–100)
Function	
Daily living	92.5 (42.6–100)
Sports	77.5 (20.0–100)
Quality of life	78.1 (31.3–100)

examination and 28.5° at the final follow-up. None of the patients showed significant loss of calcaneal height, loss of reduction, or implant failure [6]. Many studies recently reported that early ROM exercises and early weight-bearing led to better functional outcomes, with higher patient satisfaction [18]. The early ROM group exhibited less muscle atrophy, less tendon adhesion, and higher rate of patients returning to previous levels of physical activity [19]. A. Siebe De Boer et al. reported proper post-operative weight-bearing time for calcaneal fracture after systematic review. They suggested that early weight-bearing does not result in impaired outcomes compared with more conservative protocols [20]. The role of early weight-bearing is fundamentally important because of its influences on general treatment and patient's self-care ability [21]. One of the primary goals of rehabilitation is to facilitate early postoperative ambulation [22].

In this study, early ROM and early weight-bearing were attempted with heel weight-off walking at 2 weeks postoperatively. In order to minimize heel contact, an ankle brace with dorsiflexion locking or a specially designed shoe was used (Fig. 1). The brace was designed for mid-foot weight-bearing via round bottom sole and dorsiflexion locking, while allowing for plantar flexion, with the purpose of reducing heel contact in ambulation. However, due to the poor compliance of patients using the brace, a specially designed shoe (Fig. 1b) was applied after the first 25 cases. The brace or shoe could not completely prevent heel contact while ambulating. Moreover, it did not allow quantitative evaluation of how much weight-bearing would be reduced. However, it was still expected that heel loading could be minimized to a considerable extent. A crutch was used for up to 4 weeks postoperatively for adaptation to midfoot weight-bearing, and then tolerable weight-bearing ambulation without crutch was allowed. CT scans obtained after a mean duration of 11.9 months postoperatively showed that the articular step of the subtalar joint was <2 mm in 72 patients (92%). Significant reduction loss in calcaneal height, width, and Böhler angle were not found at postop 2 weeks, 3 months, and final follow-up.

The Paley grade [10] for subtalar osteoarthritis is based on the lateral view of the weight-bearing ankle. Joint space narrowing was not observed in 55 patients (70.5%) (Fig. 2); 23 patients had Paley grade 2, indicating joint space narrowing (Fig. 3); and no cases had grade 3, indicating complete loss. Complete reduction could not be obtained in 14 cases, and these patients had Paley grade 2. The mean functional score of the osteoarthritis group was 93.5, with functional grade and severity of osteoarthritis being inconsistent. Therefore, excellent functional outcomes can be expected in patients with sufficient muscle power and ROM, even with the presence of subtalar osteoarthritis. Nelson et al. reported that the rate of reoperation for subtalar fusion was 3% and

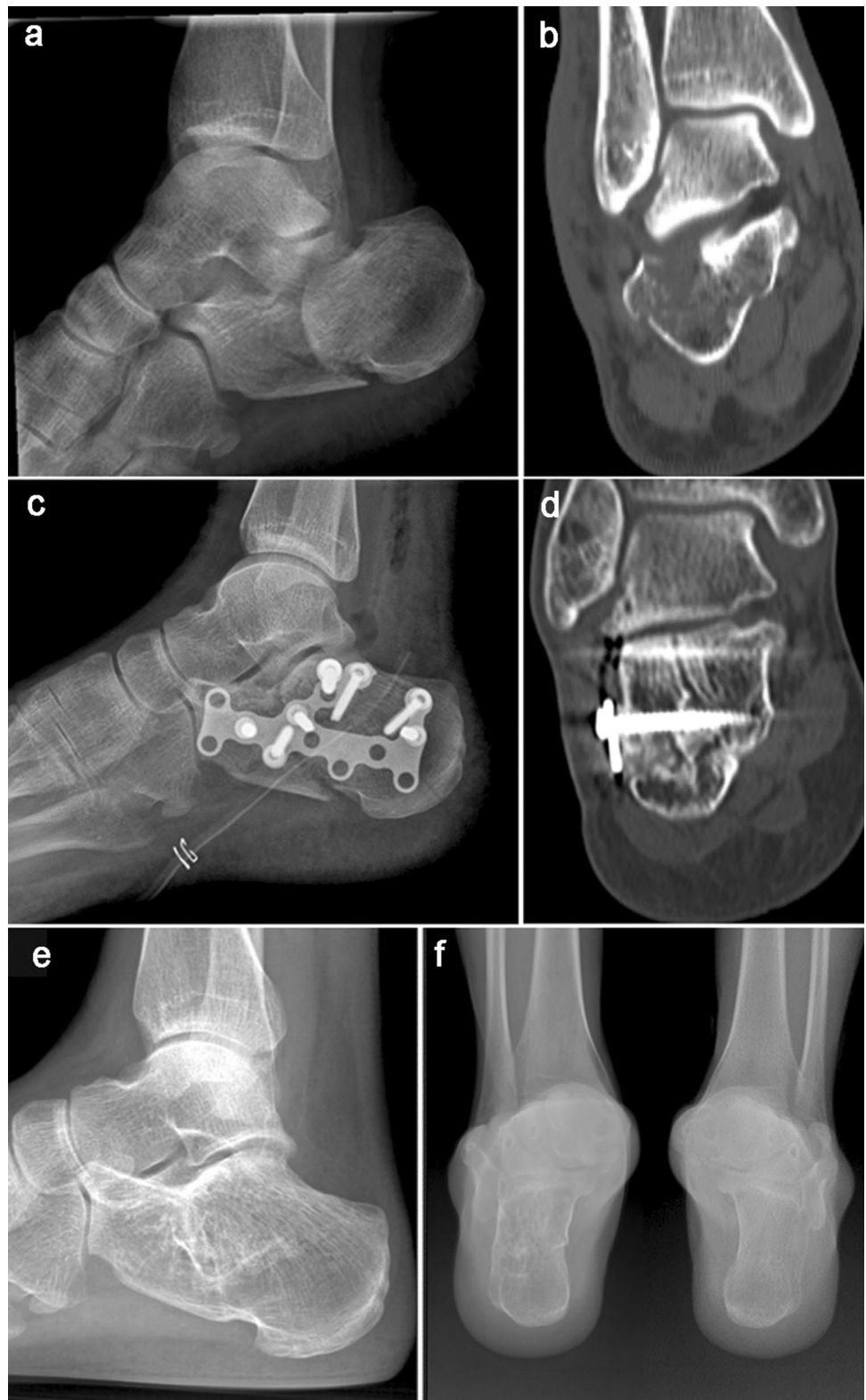
3.49% at 1 and 5 years after primary open reduction internal fixation [23]. This study, with a mean follow-up period of 45.8 months, had no cases that required subtalar fusion. Pain after calcaneal fracture surgery might be influenced more by malunions, resulting in lateral bony prominences, rather than by subtalar osteoarthritis itself. At the final follow-up, 29.5% of patients exhibited subtalar osteoarthritis, whereas no cases of lateral bump, checkrein deformity, or tarsal tunnel syndrome were found. We routinely performed implant removal and arthrolysis of subtalar joint. Since calcaneus fracture is an intra-articular fracture, fibrosis surrounding injured subtalar joint developed, which limit the joint motion. We could confirm improved joint motion after releasing fibrotic scar tissue surrounding subtalar joint during implant removal surgery. The patient was encouraged to vigorous ROM exercise after arthrolysis. Most patients reported improvements in ROM and symptoms after implant removal. Further study will be necessary about the effect of subtalar arthrolysis.

In terms of stiffness, no significant difference was found in dorsiflexion ability between the unaffected and affected sides, whereas significant differences were found in the plantar flexion and inversion. Despite active ROM exercises from 2 weeks postoperatively, the plantar flexion and inversion of the affected side was found to be about 4° and 15° less than those of the unaffected side, respectively. For the evaluation of inversion ROM, the modified McBride method was used [12] because the inversion angle reflects the stiffness of subtalar joint more accurately in the sitting position than that in the prone position. Yoo et al. showed that the group with early rehabilitation with brace after calcaneal fracture surgery exhibited better outcomes in ROM than the group with short leg casting [22]. During the functional assessment of this study, FAOS scores were found to be the lowest in sports. Among other items, daily living had the highest score of 92.5, with a score of 90 in pain, which indicated satisfactory outcomes in daily life.

The outcomes of earlier rehabilitation in this study are deemed to be excellent, with the effectiveness of brace or heel off shoe that allowed intermittent ROM exercise after self-removal, rather than cast-immobilization. Early weight-bearing might prevent muscle atrophy and facilitate ROM restoration.

The concern of reduction loss due to active early rehabilitation was presumed to be negligible, because no significant radiological changes occurred at the fracture site after earlier rehabilitation. Cancellous allo-bone graft packing into the bone defect site can contribute to the structural maintenance of posterior facet fragment reduction. Further studies on the role of bone grafting will be necessary. Lag screw fixation of the thalamic fragments and plate fixation over the lateral wall after anatomical reduction of the depressed fragment might also play an important role in preventing reduction

Fig. 2 Female, 39 years; Sander's type IIIab; Subtalar osteoarthritis is not shown. Pre-operative **a** ankle lateral view, **b** CT coronal view. Postoperative **c** ankle lateral view, **d** 9 months of follow-up, CT coronal view. 4 years of follow-up, **e** weight-bearing ankle lateral view, **f** both hind foot view



loss. In the treatment of calcaneal fractures, rather than delaying weight-bearing due to concerns of reduction loss, earlier rehabilitation with ROM exercise and ambulation is recommended, which leads to more rapid return to daily life

and more satisfactory outcomes. The key factor is that the period of immobilization should be minimized.

The limitations of this study are that outcomes of the groups using brace and shoe were not compared, and no

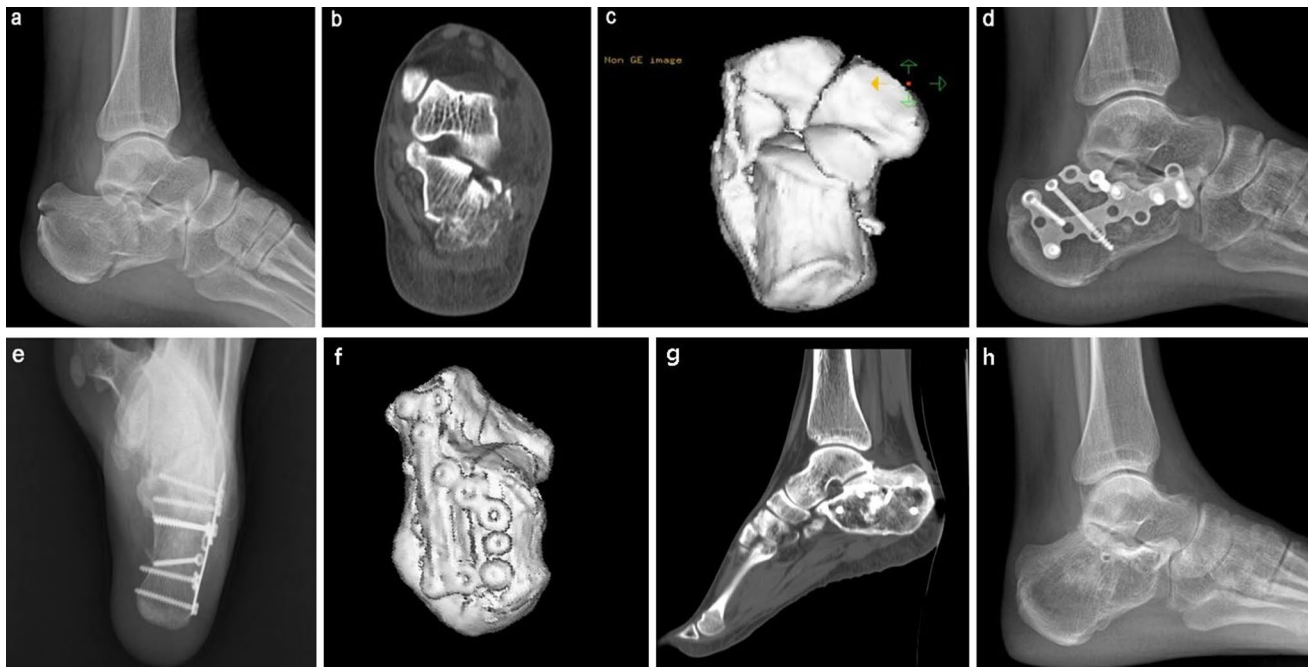


Fig. 3 Female, 47 years, Sander's type IIIab; Paley G2 subtalar arthritis. Preoperative **a** ankle lateral view, **b** CT coronal view, **c** CT 3D view. Postoperative **d** ankle lateral view, **e** calcaneus axial view, **f**,

g 9 months of follow-up, CT, **h** 5 years of follow-up, weight-bearing ankle lateral view

quantitative analysis on functional deficit according to the severity of subtalar joint osteoarthritis was performed. Wide range of follow-up periods is another limitation. Further studies may be necessary to elucidate these factors.

In conclusion, earlier rehabilitation after anatomical reduction and adequate fixation can be recommended for better outcomes for the treatment of calcaneal fractures. After starting midfoot weight-bearing walking with brace or heel off shoe from two weeks postoperatively, reduction loss of fracture site was negligible. The period of immobilization should be minimized and good functional outcomes can be expected in patients with sufficient muscle power and good ROM, even with the presence of subtalar osteoarthritis.

Author contributions ESP performed the analysis, and wrote the manuscript. YC developed the methodology and performed the analysis. JL and SHP collected the data and measured radiologic parameters. HSL was the operator of calcaneal fractures, designed the study and wrote the manuscript.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethics approval This retrospective study was approved by the Institutional Review Board of Asan Medical Center, which is a tertiary referral hospital.

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