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Radiographic and Postoperative Outcomes of Plate Versus Screw Constructs in Open Reduction and Internal Fixation of Calcaneus Fractures via the Sinus Tarsi

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Abstract

Background: Intra-articular fractures of the calcaneus are a common injury to the hindfoot following high-energy trauma to the lower extremity. Treatment of these fractures has evolved. Due to the concern of wound complications associated with extensile open treatment, smaller incision techniques, such as the sinus tarsi approach, are increasing in popularity. A number of fixation strategies are utilized with this approach, and it is unknown which most accurately restores radiographic alignment. The purpose of this study was to compare the postoperative radiographic outcomes of a plate and screw construct versus a cannulated screw construct when using the sinus tarsi approach for open reduction and internal fixation (ORIF) of calcaneus fractures.

Methods: After institutional review board approval, records for all patients treated surgically at our institution for calcaneus fractures from 2012 to 2017 were reviewed. Inclusion criteria were intra-articular calcaneus fractures, patients aged 18 years or older, and use of the sinus tarsi approach. Exclusion criteria were open fractures and fractures with less than 6 weeks of postoperative weightbearing, which were excluded for radiographic outcomes. A total of 51 fractures underwent ORIF using cannulated screws alone (group 1), and 23 fractures underwent ORIF using a sinus tarsi plate (group 2). Sixty-one fractures (41 vs 20, respectively) met criteria for radiographic comparison. The primary outcomes of interest included pre- and postoperative Bohler and Gissane angles, wound complications, unplanned return to the operating room (OR), and cost comparison.

Results: There was no statistically significant difference between preoperative Bohler angles for group 1 (14.4 degrees) versus group 2 (12.2 degrees) ($P = .44$), nor was there a significant difference between postoperative Bohler angles for group 1 (30.1 degrees) versus group 2 (27.1 degrees) ($P = .14$). Similarly, preoperative Gissane angles for group 1 (130.5 degrees) and group 2 (133.4 degrees) ($P = .54$) and postoperative Gissane angles for group 1 (118.2 degrees) and group 2 (119.8 degrees) ($P = .44$) showed no statistically significant difference. There were a total of 3 wound complications in group 1 versus 2 wound complications in group 2 ($P = .66$). There was no statistically significant difference in operative duration ($P = .97$) or the number of unplanned returns to the OR between the 2 groups ($P = .68$). Based on the implants used at this institution, and depending on the number of screws used, the estimated cost range of a plate construct was $1070 to $1235, while the estimated cost range of a cannulated screw construct was $717 to $1264.

Conclusion: When comparing the cannulated screw and plate and screw fixation techniques, there was no difference in restoration of the Bohler and Gissane angles. Furthermore, the amount of angular correction achieved by initial reduction showed no statistically significant difference between groups, and the amount of reduction lost between initial and final postoperative radiographs showed no statistically significant difference between groups. With regard to the 2 techniques, there was no statistically significant difference in rates of postoperative complications and return to the OR. Our data

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suggest that fixation using cannulated screws alone versus sinus tarsi plate provides similar radiographic outcomes and risk of complications. The 2 techniques were also similar in terms of implant costs. Our results indicate that either technique effectively improved radiographic parameters.
Level of Evidence: Level III, retrospective comparative study.

Keywords: calcaneus, fracture, sinus tarsi, plate, screw, Bohler, Gissane, trauma

Introduction

Intra-articular fractures of the calcaneus are common injuries to the hindfoot following high-energy trauma to the lower extremity. The optimal treatment for displaced intra-articular calcaneus fractures is controversial. Historically, studies have favored nonoperative treatment for calcaneus fractures due to the high risk of complications.[8,13,15] However, the sequelae of nonoperatively treated calcaneus fractures are well known and include malunion, subtalar arthritis, tibiotalar impingement, and subfibular impingement.[4,7,17,19] In order to avoid these complications, surgeons have increasingly recommended open surgical treatment for these injuries. Recent studies have demonstrated the benefits of operative management with regard to improved pain, function, satisfaction, and radiographic evidence of subtalar arthritis.[2,6,9,20]

The lateral extensile approach has become a commonly utilized approach to address intra-articular calcaneus fractures.[5] While this strategy of open reduction and internal fixation (ORIF) allows excellent visualization of the fracture and direct articular reduction, it carries a high risk of wound complications. Studies have reported wound complication rates of 17% to 25%.[2,3,6,10] Due to high rates of complications with the traditional extensile lateral approach, surgeons have sought alternative methods to address these complicated injuries. These techniques attempt to minimize soft tissue trauma while also allowing adequate visualization for reduction of the fracture fragments.[14] One less invasive method for approaching the calcaneus is the sinus tarsi approach. This approach involves a smaller incision with dissection through the sinus tarsi and direct visualization of the articular surfaces.[23] In one study, clinical and radiographic results were similar between the extensile lateral and sinus tarsi approaches, with fewer soft tissue complications found in the sinus tarsi group.[14]

While studies have shown fewer wound complications with the sinus tarsi approach,[14] the choice of fixation construct is still controversial. Many studies evaluating the sinus tarsi approach utilized a plate construct for fixation of the fracture or a construct with only cannulated screws, and both methods have demonstrated positive postoperative outcomes.[1,2,9,11,12,14,16,18,20,21,23] It is unknown whether a screw or plate strategy better achieves and maintains anatomic reduction as assessed via radiographs. To our knowledge, no study has compared sinus tarsi fixation techniques in terms of anatomic reduction and postoperative outcomes. The aim of our study was to assess the radiographic outcomes and complications of these 2 fixation techniques. We also aimed to compare the cost of implants associated with each technique. We hypothesized that plate constructs would have superior postoperative radiographic reductions compared with screw constructs alone.

Methods

After institutional review board approval, records for all patients treated surgically for calcaneus fractures at our institution from 2012 to 2017 were reviewed. Inclusion criteria were intra-articular fractures, patients aged 18 years or older, use of the sinus tarsi approach, and surgeries performed by any orthopedic surgeon at our institution. Excluded patients were those with open fractures, age less than 18 years, and radiographic follow-up less than 6 weeks. Using these criteria, 74 fractures were identified for inclusion and analysis. All surgeries were performed by fellowship-trained foot and ankle or trauma orthopedic surgeons. Fifty-one fractures underwent ORIF using cannulated screws alone, and 23 fractures underwent ORIF using a sinus tarsi plate. For the purposes of radiographic comparison, only patients who underwent 6 or more weeks of weightbearing postoperatively were included. If a patient did not have an adequate period of weightbearing to effectively assess maintenance of reduction due to loss to follow-up, concomitant injuries, or postoperative complications, they were excluded from radiographic analysis. With this stipulation, there were 41 fractures in group 1 and 20 in group 2 eligible for assessment of radiographic outcomes. Pre- and postoperative radiographs were reviewed. The radiographic parameters of Bohler and Gissane angles were measured both preoperatively and postoperatively. Collected demographic data included age, gender, race, body mass index (BMI), and patient comorbidities (eg, smoking, diabetes). Patient charts were reviewed to determine Sanders classification (computed tomography), length of follow-up, wound complications, and unplanned return to the operating room (OR). Data on costs of implants used at our institution were obtained for each construct type. Using radiographs of patients in the study, we determined the cost variability

Table 1. Patient Demographics for Groups 1 and 2.

Parameter	Cannulated Screws (Group 1)	Plate (Group 2)	*P* Value
No. of patients	51	23	
Mean BMI	26.3	25.6	.99
Gender, no.			.32
Male	34	18	
Female	17	5	
Mean age, y	43	42	.83
Smoking status, no.			.81
Smoker	34	16	
Nonsmoker	17	7	
Diabetic patients, no.	3	1	
Mechanism of injury, no.			.31
MVC	20	6	
Fall from height	31	17	
Laterality, no.			.78
Right	27	13	
Left	24	10	
Sanders classification, no.			.97
IIA	12	5	
IIB	8	4	
IIC	5	3	
III	26	11	
Complications, no.			
Superficial infection	1	0	
Wound dehiscence	0	2	
Deep infection	2	0	
Total wound complications	3	2	.66
Painful hardware	5	2	.88
Return to OR	7	4	.68
Mean operative time, min	120.3	120.6	.96
Mean follow-up, weeks	42.7	54.1	.18

Abbreviations: BMI, body mass index; MVC, motor vehicle collision; OR, operating room.

based on the minimum and maximum number of screws used in the constructs analyzed in our study. For the data analysis, all continuous variables were assessed using a Student *t* test, and all categorical variables were assessed with Pearson's chi-square test. Significance was set at 5%.

Seventy-four patients met inclusion criteria. Fifty-one patients were treated with the cannulated screw technique (group 1), and 23 were treated with the plate and screw technique (group 2). Patient demographics are displayed in Table 1. Group 1, the screw group, was composed of 34 males and 17 females with a mean age of 43 years (range, 18-76 years). Group 2, the plate group, was composed of 18 males and 5 females with a mean age of 42 years (range, 22-63 years). In the screw group, there were 27 right-sided fractures and 24 left-sided fractures. Fracture classification revealed 12 Sanders IIA, 8 Sanders IIB, 5 Sanders IIC, and 26 Sanders III patterns. In the plate group, there were 13 right-sided fractures and 10 left-sided fractures. Fracture classification revealed 5 Sanders IIA, 4 Sanders IIB, 3 Sanders IIC, and 11 Sanders III patterns. There were no significant differences between age, gender, BMI, laterality, Sanders classification, smoking status, length of follow-up, or injury mechanism between the patients in the 2 groups (Table 1).

Surgical Techniques

Cannulated Screws

Depending on fracture configuration, a Steinmann pin was introduced into the plantar medial tuberosity (joint depression fractures) or the dorsolateral tuberosity (tongue-type fractures). Once radiographic reduction of the medial wall was obtained, it was held with 2 to 3 guidewires placed from posterior to anterior along the medial wall. The Steinmann pin was removed. A sinus

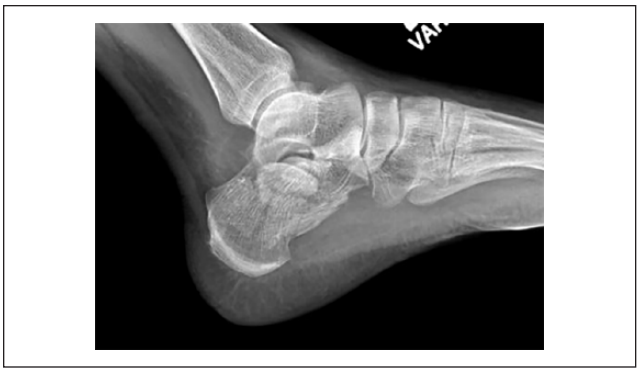

Figure 1. Lateral preoperative radiograph of a left foot. This figure displays lateral injury films of one patient with an intra-articular calcaneus fracture. Noteworthy features include a depressed posterior facet of the subtalar joint and a secondary fracture line exiting inferiorly through the calcaneus.

Figure 2. Lateral postoperative radiograph of the foot from Figure 1. This figure shows radiographs of the patient's foot following the cannulated screw technique. Restoration and maintenance of both the height of the posterior facet and length of the calcaneus are observed.

tarsi approach was made and the displaced posterior facet fragments were reduced to the constant fragment and held temporarily in place. Once an anatomic reduction was achieved, 1 to 2 (more if needed) 3.0 cannulated screws were inserted from lateral to medial along the posterior facet. Following placement of the facet screws, 4.0 cannulated screws were inserted over the guidewires originally placed along the medial wall. Final reduction and fixation were confirmed using direct visualization and fluoroscopy (Figures 1 and 2).

Plate and Screws

To begin, following sinus tarsi exposure, the posterior facet fragment was identified and elevated under fluoroscopic guidance. Once an anatomic reduction of the posterior facet

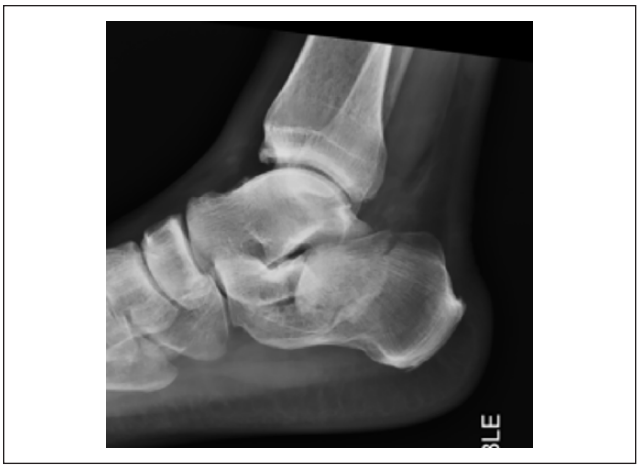

Figure 3. Lateral preoperative radiograph of a left foot. This figure displays lateral injury films of one patient with an intra-articular calcaneus fracture. Noteworthy features include a depressed posterior facet of the subtalar joint and a secondary fracture line exiting inferiorly through the calcaneus.

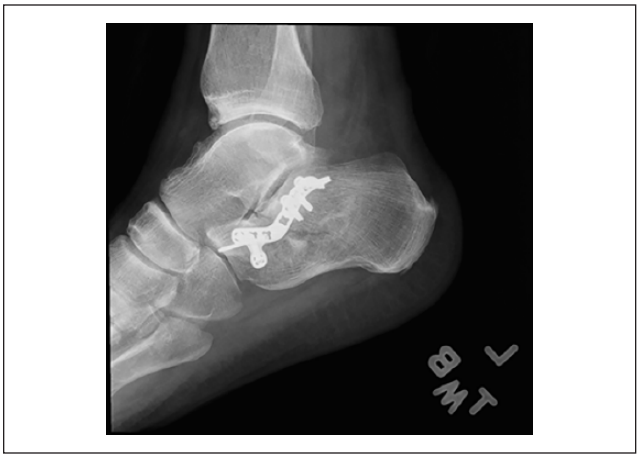

Figure 4. Lateral postoperative radiograph of the foot from Figure 3. This figure displays radiographs of the patient's foot following the sinus tarsi plate technique. Restoration and maintenance of both the height of the posterior facet and length of the calcaneus are observed.

was achieved, 2 to 3 Kirschner wires were placed in a posterior-to-anterior orientation in order to temporarily hold the reduction. Using a lag technique, metaphyseal screws were then placed across the posterior facet to obtain compression across the fracture. The Kirschner wires were removed, and the posterior facet was reduced to the anterior process using direct visualization. A plate was then placed on the lateral border of the calcaneus spanning to the anterior process. With use of locking screws, it was first secured to the anterior process and then to the posterior facet. Once the plate was secured, direct visualization and fluoroscopic images were obtained to confirm anatomic reduction and appropriate hardware placement (Figures 3 and 4).

Table 2. Radiographic Parameters for Groups 1 and 2.

Parameter	Cannulated Screws (Group 1)	Plate (Group 2)	*P* Value
Patients	41	20	
Initial Bohler, deg	14.4	12.2	.44
Initial Bohler correction amount, deg	20.3	19.4	.77
Final Bohler, deg	30.1	27.1	.14
Reduction lost, deg	3.9	4.5	.59
Initial Gissane, deg	130.5	133.4	.54
Initial Gissane correction amount, deg	18.6	19.9	.73
Final Gissane, deg	118.2	119.8	.61
Reduction lost, deg	6.1	6.5	.86

Abbreviation: deg, degrees.

Results

Sixty-one patients met inclusion criteria for radiographic comparison. Radiographic parameters are displayed in Table 2. In the screw group, the average preoperative and postoperative Bohler angles were 14.4 degrees and 30.1 degrees, respectively. In the plate group, the average preoperative and postoperative Bohler angles were 12.2 degrees and 27.1 degrees, respectively. There was no significant difference between preoperative and postoperative Bohler angles in the screw or plate groups. In the screw group, the average preoperative and postoperative Gissane angles were 130.5 degrees and 118.2 degrees, respectively. In the plate group, the average preoperative and postoperative Gissane angles were 133.4 degrees and 119.8 degrees, respectively. There was no significant difference between preoperative and postoperative Gissane angles in the 2 groups. Additionally, there was not a statistically significant difference between group 1 and group 2 in the amount of angular correction achieved with initial reduction. There was also no statistically significant difference in the amount of reduction lost between the initial and final postoperative radiographs between groups. Furthermore, there was no statistically significant difference between the operative times between the 2 fixation techniques.

In the screw group there were a total of 8 complications: 1 superficial infection requiring oral antibiotic treatment, 2 deep infections, and 5 episodes of painful hardware, necessitating 7 total unplanned returns to the OR. In the plate group there were a total of 4 complications: 2 wound dehiscences and 2 episodes of painful hardware, necessitating 4 unplanned returns to the OR. There was no statistically significant difference in the rate of total complications, as well as each individual complication type with the numbers available. There was also no statistically significant difference in the number of unplanned returns to the OR.

Cost was also analyzed. Based on the implants used at this institution, and depending on the number of screws used, the estimated cost range of a plate construct was $1070 to $1235, while the estimated cost range of a cannulated screw construct was $717 to $1264.

Discussion

Intra-articular fractures of the calcaneus carry a heavy burden of recovery and postoperative complications in the young, working population. The treatment of these fractures has generated debate between operative and nonoperative strategies. In the early 1990s, Benirschke and Sangeorzan published one of the first descriptions of an operative technique for intra-articular calcaneus fractures that provided promising outcomes and lower morbidity. Principles of care were anatomic reduction, rigid internal fixation, and early functional motion.[5] This technique, using the lateral extensile approach, over time became the conventional method of fixation of these fractures when a patient and surgeon decided on surgical management. Increasing use of this method resulted in further inquiry into its outcomes, and a number of studies noted high rates of wound complications.[2,6,10] These wound complications were magnified in patients with comorbidities such as diabetes and smoking, precluding many surgeons from recommending ORIF in these patient populations. Unfavorable rates of wound complications have caused surgeons to investigate alternative surgical techniques with less trauma to the soft tissues, but the principles of anatomic reduction, rigid fixation, and early motion remain the same.

In our study, we demonstrated 2 methods of fixation that provided adequate restoration of normal radiographic parameters of the calcaneus. The literature supports the fact that anatomic reduction correlates with improved outcomes in the surgical treatment of these fractures.[9,22] The choice of construct was typically surgeon dependent, and there were no morphological characteristics of a fracture that may have swayed a surgeon's decision to choose one strategy over the other. Both tongue and depression variants were included in each group. From a perspective of fixation mechanics, articular reduction was achieved by both techniques in a similar fashion—direct visualization and screws for fixation. The constructs differed in that calcaneal length was maintained with either posterior-to-anterior screws or a plate spanning from the posterior tuberosity to the anterior

process. In general, there were surgeons who used only plates and surgeons who used only cannulated screws depending on training and familiarity. The timing of ORIF was not a factor in decision-making for either construct. However, due to minimal soft tissue manipulation and lower concern for wound complication, we believe that either of these strategies can be safely employed closer to the time of injury than the lateral extensile approach.[1,9,14]

When comparing the cannulated screw and plate and screw fixation techniques, both techniques equivalently restored the Bohler and Gissane angles. Both techniques showed similar rates of postoperative complications such as painful hardware, wound infection, and return to the OR. Both groups showed improvement in radiographic parameters compared with preoperative measurements. Furthermore, there was no statistically significant difference in the final correction restored by either technique. Looking even more closely at the 2 cohorts, and with regard to the Bohler and Gissane angles, there was no statistically significant difference between the amount of correction acquired in the initial postoperative radiographs, nor was there a statistically significant difference in the amount of angulation lost between initial and final postoperative radiographs. This would suggest that both techniques have similar power in both achieving and maintaining an adequate radiographic reduction over time. Wound complications and return to the OR (typically due to painful hardware) were not significantly different in either group, even though we may expect prominent screwheads in the posterior tuberosity to cause more symptomatic hardware. The percentage of total wound complications with the sinus tarsi approach in our study was 6.7%, which is similar to past studies reporting rates of 3% to 13%.[1,9,14] The rates of complication with both techniques proved to be much lower than the classically described rates of complications of extensile lateral treatment of calcaneus fractures, with reports of wound complications ranging from 17% to 25%.[2,3,6,10]

Our study is not without limitations, and the most notable is sample size. The vast majority of procedures were performed by 1 of 3 surgeons at 1 facility. Of note, the number of patients in group 1 was twice that of group 2 (51 vs 23). This remained true for radiographic comparison with 41 versus 20 fractures in group 1 and group 2, respectively. Furthermore, if superficial infection is excluded, the rates of deep wound complication (dehiscence, deep infection) for screws versus plate are 4.0% and 8.7%, respectively. Statistically, this does not represent a significant difference ($P = .4$), but the deep complication rate for plates is more than twice that for screws. Both of these rates of wound complication, however, are lower than the rates seen in the extensile approach described elsewhere in this article.[2,6,10] Each group also falls within the range of complication rates mentioned above for the sinus tarsi approach in previous literature.[1,9,14] Nonetheless, this discrepancy in our data highlights the necessity for further inquiry with larger cohorts into these 2 fixation techniques as the sinus tarsi approach becomes increasingly utilized for the treatment of calcaneus fractures.

Finally, one well-known sequela of the injury is posttraumatic arthritis requiring subtalar fusion. Outcomes of subtalar fusion are largely dependent on the quality of the initial operative treatment. Radnay et al showed that initial surgical treatment, with regard to correction of calcaneal height, shape, and alignment, positively affected the outcome of eventual subtalar fusion by re-creating a more anatomic calcaneus, as the restored anatomy does not require a distraction fusion procedure.[17] Both sinus tarsi fixation techniques in this study provide the ability to restore normal anatomy without increasing the risk of wound complications.

Prior studies have demonstrated the viability of the sinus tarsi approach with regard to restoration of radiographic parameters as well as improvement in postoperative wound complications, functional outcomes, and patient satisfaction.[1,2,9,11,12,14,16,18,20,21,23] These studies have typically used either a cannulated screw or a plate technique similar to the ones described in this article. Our data suggest that, in addition to similar cost and operative time, fixation using cannulated screws alone or a sinus tarsi plate provides similar radiographic and postoperative outcomes when compared head-to-head.

Conclusion

When using the sinus tarsi approach for intra-articular calcaneus fractures, fixation with cannulated screws alone versus a plate and screw construct resulted in similar radiographic and postoperative outcomes. Both fixation methods have equivalent abilities to restore and maintain Bohler and Gissane angles while demonstrating a lower complication rate than the extensile lateral approach.

Editor's Note

The authors appropriately point out that their small sample size is a limitation. While no power study was performed, it is clear that the findings of equivalency in outcomes may not have held up with a larger group of patients. Also, the very short follow-up period limits the radiographic outcomes to showing that 6 weeks of weightbearing did not result in loss of radiographic correction. However, the vast majority of calcaneus fractures would be healed by then, so they did successfully demonstrate that each fixation construct was able to maintain the alignment during the bone healing process.

Declaration of Conflicting Interests

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