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A comparison of union rates and complications between single screw and double screw fixation of sliding calcaneal osteotomy

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ABSTRACT

Background: The number of screws used for sliding calcaneal osteotomy fixation has not been examined in the literature. The purpose of this paper is to examine this topic.
Methods: Retrospective chart review was performed on 190 patients who met selection criteria. We compared complication risk for single versus double screw, headed versus headless screw, and short versus longitudinal incision cases.
Results: The mean age was 48.4 (18–83) years and average follow up was 28 (12–150) weeks. All cases achieved radiographic union. Overall complication rate was 19.5% (37/190). Risk of complication did not differ significantly between single and double screw (RR: 1.170; 95% CI: 0.66–2.09; $p = 0.594$) or short and extended incision groups (RR: 0.868; 95% CI: 0.42–1.80; $p = 0.704$). Risk of complication differed significantly between headed and headless screw fixation (RR: 5.558; 95% CI: 2.69–11.50; $p < 0.0001$).
Conclusions: Single screw fixation of sliding calcaneal osteotomy achieves similar outcomes as double screw fixation. Headless screws are advantageous for minimizing hardware pain and subsequent hardware removal.

1. Introduction

Sliding calcaneal osteotomy is a common operative procedure used to correct hindfoot malalignment [1–5]. Different methods of fixation have been described and include staples [6], plates [7], and most commonly cannulated screws [8,9]. Previous studies have examined differences between these various techniques and their association with hardware removal [10]. Among screw fixation, screw diameter and insertion technique have also been studied with regard to their effect on painful hardware, and more narrow screws have been found to be beneficial [9,11]. However, to our knowledge, the number of screws of the same diameter used for screw fixation has rarely been examined. While biomechanical investigation has raised concerns regarding possible rotational instability with one screw fixation [8], this has not been reproduced in the clinical literature. Currently, the number of screws used for fixation is based on the surgeon's experience [11], without sufficient data comparing the outcomes and complications between patients who have undergone single and double screw fixation.

Previously, Abbasian et al. compared three different methods (headless screw, headed screw, and lateral locking plate) of calcaneal osteotomy fixation. They reported a 100% union rate in the screw fixation cohort which utilized only a single screw and while they commented on the minimal need for placement of a second screw, they did not directly compare outcomes between single screw fixation and double screw fixation. Additionally, the authors found headed screws carried the greatest risk for hardware removal.

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The aim of the current study was to present and compare outcomes between single screw fixation and double screw fixation in a moderately sized cohort of patients who underwent sliding calcaneal osteotomy for the treatment of hindfoot malalignment. Additionally, we performed subgroups analysis to assess the extent to which screw type (headed vs. headless) and incision length (short vs. extended) affected outcomes.

2. Methods

Following Institutional Review Board approval, a retrospective chart review was performed on 380 patients who underwent sliding calcaneal osteotomy as part of the surgical treatment of hindfoot deformities at our institution from 2009 to 2015. These patients were identified using the CPT code for calcaneal osteotomy (28300). Types of osteotomies performed included medial displacement or "medial slide" for valgus deformity and lateral displacement or "lateral slide" for varus deformity. Inclusion criteria were patients 18 years or older, with symptomatic varus or valgus hindfoot deformities. Exclusion criteria were patients under 18 years old, patients who had previously undergone ankle arthroplasty, patients with less than 12 weeks of follow-up, patients with concomitant osteotomies besides the medial or lateral slide, and patients who had fixation of their osteotomy with either plates or staples. Patient's operative records, pre/post-operative radiographs, and clinical notes were reviewed for evaluation of overall complications, infection rate, hardware related pain, and revision surgery.

Patients were then separated into two groups based on the number of screws used to fix their osteotomy (one vs. two). Demographic information was compared between each group, with a Student t test being used to compare age at surgery and body mass index, and Fisher's exact test being used to compare gender and hindfoot alignment. Next the union rates between the two groups were compared and relative risk (RR) and 95% confidence interval (CI) regarding complications (hardware related pain & removal, superficial and deep infection, wound dehiscence and skin necrosis, and nerve injury) were computed. RRs were calculated for total complication rate as well as each individual complication. Next, subgroup analysis was performed between headed and headless screw fixation. Difference in total complication rate between all patients who underwent headed vs. those who received headless screws was calculated by producing a RR and 95% CI for headed screws. Then each individual complication was compared between headed and headless fixation in both the one and two screw groups to yield a RR and 95% CI for each. Finally, subgroups analysis was performed in the same fashion to compare patients with a short (under 5 cm) incision and those with an extended (over 5 cm) incision.

2.1. Operative technique

Patients were placed in the supine position with a bump under the hip on the operative side to allow better lateral exposure. One of two types of skin incisions (short or extended) was used, but all incisions included the superior aspect of the posterior tuberosity of the calcaneus just anterior to the insertion of the Achilles tendon. Short incisions were usually used when only calcaneal osteotomy was performed. Extended incision was used only while when concomitant procedures soft tissues procedures like peroneal tendon debridement, lateral ligament reconstruction were performed in the same setting. The choice of one versus two screws as well as the use of headed versus headless screws was based purely on surgeons preference and independent of any concomitant procedure performed. All exposures were performed with a vertical incision with the exception being those performed by an extended incision. The vertical incision was made 1 cm posterior to the fibula and 2 cm proximal to the superior aspect of the calcaneus extending distally at a 45° angle with the plantar surface of the foot. Blunt dissection was carried out to the sural nerve which was identified and retracted, and then sharp dissection was carried out down to the periosteum of the calcaneus. Periosteum was stripped using a key elevator and osteotomy was performed using an oscillating saw at an angle perpendicular to the longitudinal axis of the calcaneus and at 45° to the weight bearing surface, taking care not to breech medial cortex [12,13]. Osteotomy was completed with an osteotome while taking care not to injure the tarsal tunnel region. After completion of the osteotomy, two laminar spreaders were inserted across the osteotomy site. The branches of the plantar nerve and the posterior tibial artery were visualized and protected, and the osteotomy fragment was translated either laterally or medially. After using fluoroscopy to visualize positioning of the osteotomy fragment from both a lateral and axillary views, a 1–2 cm incision was made on the posterior heel, along middle axis of the foot, while taking care to avoid the weight bearing skin. A Kirschner wire was inserted to guide the subsequent insertion of one 6.5 mm diameter screw. In double screw fixation another incision was made 1–2 cm superior or inferior to the first for insertion of the second 6.5 mm diameter screw. Positioning was confirmed with fluoroscopy and the wound was irrigated and 2-0 Monocryl, 4-0 Monocryl, and 3-0 nylon were used to close the deep tissue, subcutaneous tissue, and skin, respectively. The limb was then placed in a well-padded splint and the patient was made non-weightbearing for 6 weeks. Radiographs were taken at 2 weeks, 4 weeks, 6 weeks, and 12 weeks post-operatively.

3. Results

A total of 190 (112 male, 78 female) patients met the study's inclusion criteria. Average age was 48.4 (range, 18–83) years and average follow up was 28 (range, 12–150) weeks. Union rate of the osteotomy was 100% in the study population at 3 months follow-up regardless of the operative approach, number of screws, or type of screws used.

Eighty-five of the 190 included patients underwent fixation by a single cannulated screw (44.7%), including 46 patients with valgus deformity and 39 with varus deformity of the hindfoot. One hundred and five patients underwent fixation by two cannulated screws (55.3%), including 44 patients with valgus deformity and 61 with varus deformity of the hindfoot. A total of 100 patients underwent lateral slide osteotomy (52.6%) and 90 received a medial slide osteotomy (47.4%). Thirty-two patients had an extended lateral incision (16.8%) and 158 patients had a short lateral incision (83.2%). There was no significant difference in gender ($p = 0.182$), hindfoot alignment ($p = 0.109$), or mean body mass index (32.42 vs. 30.45, $p = 0.058$) between the single and double screw groups. However, patients in the single screw group were significantly younger (mean age 45.43 vs. 51 years, $p = 0.008$) (Table 1).

3.1. Single screw versus double screw fixation

Overall 37 complications (19.5%) occurred in the 190 cases of sliding calcaneal osteotomy. 18 complications (21.2%) occurred out of 85 single screw cases and 19 complications (18.1%) occurred out of 105 double screw cases. The complication rates between the single screw group and the double screw group did not differ significantly (RR: 1.170; 95% CI: 0.66, 2.09; $p = 0.594$). Deep infection rates did not differ significantly between the single screw (3.53%, 3/85) and double screw (4.76%, 5/105) groups (RR: 0.741; 95% CI: 0.18, 3.01; $p = 0.676$). Hardware related pain

Table 1
Demographic data for single screw and double screw fixation groups.

	Single screw (N = 85)	Double screw (N = 105)	*p* value
Mean age (years)	45.43	51	0.008
Mean BMI (kg/m^2)	32.42	30.45	0.058
Gender			
Male (n)	30	48	0.182
Female (n)	55	57	
Hindfoot alignment			
Valgus (n)	46	44	0.109
Varus (n)	39	61	

necessitating hardware removal occurred in 13 of 85 cases (15.29%) in the single screw group and in 9 of 105 cases (8.57%) in the double screw group (RR: 1.784; 95% CI: 0.80, 3.97; $p = 0.156$). Nerve injury occurred in 1.17% (1/85) of single screw cases and in 4.76% (5/105) of double-screw cases (RR: 2.47; RR: 0.02, 2.07; $p = 0.197$). These findings are summarized in Table 2.

3.2. Headed versus headless screws

Seventy-five patients (39.5%) underwent headed screw fixation while 115 patients (60.5%) underwent headless screw fixation. Twenty-nine complications occurred in patients who underwent headed screw fixation (38.7%), while eight complications occurred in patients who underwent headed screw fixation (7.0%). Thus headed screw fixation was associated with significantly higher complication rates (RR: 5.558; 95% CI: 2.69, 11.50; $p < 0.0001$). Of the patients who underwent single screw fixation (n = 85), 37 (43.5%) had headed screws used, while 48 (56.5%) had headless screws used. In patients who underwent double screw fixation (n = 105), 38 (36.2%) patients were fixed with both screws being headed, while 67 (63.8%) were fixed with two headless screws.

Among patients with single screw fixation, hardware related pain necessitating hardware removal surgery occurred in 10 of 37 patients (27.03%) in the headed screw group and 3 of 48 patients (6.25%) in headless screw group, and thus significantly more likely in the headed screw group (RR: 4.324; 95% CI: 1.28, 14.60; $p = 0.018$). Deep infection showed no significant difference occurring in 2 of 37 cases in the headed group (5.4%) and 1 of 48 cases in headless screw group (2.1%) (RR: 2.595; 95% CI: 0.24, 27.53; $p = 0.428$). Superficial infections did not occur in patients from either group. The incidence of nerve injury was not significantly different, occurring 1/37 (2.7%) in the headed screw groups and 0/48 (0%) in the headless screw group (RR; 3.868; 95% CI: 0.16, 92.32; $p = 0.403$).

In patients with double screw fixation, the rate of hardware related pain necessitating removal surgery was 8/38 (21.05%) headed screw group and 1/67 (1.49%) in headless screw group, and this increased rate of removal in the headed screw group was significant (RR: 14.105; 95% CI: 1.83, 108.52; $p = 0.011$). Deep infection rate was 2/38 (5.26%) in the headed screw group and 1/67 (1.5%) in the headless screw group, displaying no significant difference (RR: 3.526; 95% CI: 0.33, 37.61; $p = 0.296$). Superficial infection rate was not significantly different, occurring 2/38 (5.3%) in the headed screw group and 0/67 (0%) in the headless screw group (RR: 8.718; 95% CI: 0.42, 177.00; $p = 0.158$). The incidence of nerve injury was not significantly different, at 3/38 (7.9%) in the headed screw group and 2/67 (3.0%) in the headless screw group (RR: 2.605; 95% CI: 0.45, 14.90; $p = 0.281$) (Table 3).

Radiographs of all four types of fixation (single headed screw, single headless screw, double headed screw, and double headless

Table 2
Complication rates in single screw vs. double screw fixation groups. Relative risk of given complication with one screw fixation compared to two screw fixation.

	Single screw (N = 85)	Double screw (N = 105)	RR	95% CI	*p* value
Total complications	18/85	19/105	1.170	0.66–2.09	0.594
Hardware related pain & removal	13/85	9/105	1.784	0.80–3.97	0.156
Deep infection	3/85	3/105	1.235	0.26–5.96	0.793
Superficial infection	0/85	2/105	0.247	0.01–5.07	0.364
Any infection	3/85	5/105	0.741	0.18–3.01	0.676
Skin necrosis	1/85	0/105	3.698	0.15–89.63	0.421
Nerve injury	1/85	5/105	0.247	0.02–2.07	0.197
Complications with headed screws	14/37	15/38	0.959	0.54–1.70	0.884
Complication with headless screws	4/48	4/67	1.396	0.37–5.31	0.625
Complication with short incision	17/75	13/83	1.447	0.75–2.78	0.266
Complication with extended incision	1/10	6/22	0.367	0.05–2.66	0.321

Table 3
Comparison of complications in headed vs. headless screws. Relative risk (RR) of complication with headed screw fixation in comparison to headless screw fixation.

	Total complication	Headed	Headless	RR	95% CI	*p* value
Single screw						
Hardware related pain	13/85(15%)	10/37	3/48	4.324	1.28–14.60	0.018
Deep infection	3/85(3%)	2/37	1/48	2.595	0.24–27.53	0.428
Superficial infection	0/85 (0%)	0/37	0/48	1.290	0.02–63.51	0.898
Skin necrosis	1/85 (1%)	1/37	0/48	3.868	0.16–92.32	0.403
Nerve injury	1/85 (1%)	1/37	0/48	3.868	0.16–92.32	0.403
Double screw						
Hardware related pain	9/105 (8%)	8/38	1/67	14.105	1.83–108.52	0.011
Deep infection	3/105 (2%)	2/38	1/67	3.526	0.33–37.61	0.296
Superficial infection	2/105 (1%)	2/38	0/67	8.718	0.42–177.00	0.158
Skin necrosis	0/105 (0%)	0/38	0/67	1.744	0.03–86.15	0.779
Nerve injury	5/105(4%)	3/38	2/67	2.605	0.45–14.90	0.281

Fig. 1. Single screw headed fixation.

screw) are shown in Figs. 1–4 and a photograph of the screws is shown in Fig. 5.

3.3. Type of incision

158 patients (83.2%) had a short incision while 32 patients (16.8%) had an extended incision. Thirty complications occurred in patients who received a short incision (complication rate = 19%)

Fig. 2. Single screw headless fixation.

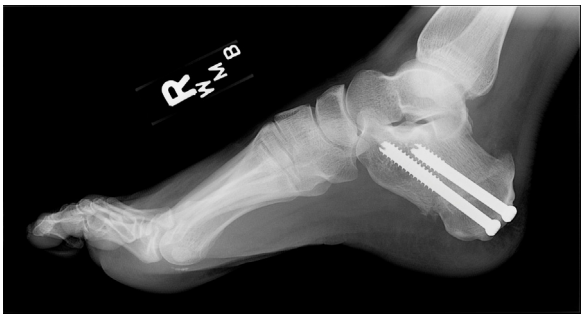

Fig. 3. Double screw headed fixation.

while seven complications occurred in patients who received an extended incision (complication rate = 21.9%). These complications rates did not differ for patients with a short incision when compared to those with an extended incision (RR: 0.868; 95% CI: 0.42, 1.80; $p = 0.704$). The individual complication rates between

Fig. 4. Double screw headless fixation.

Fig. 5. Headless (left) and headed screws (right).

Table 4
Comparison of the complication rates between of types of incision in single screw vs. double screw fixation. Relative risk (RR) for complication with short incision in comparison to extended incision.

	Short	Extended	RR	95% CI	*p* value
Single screw					
Hardware related pain & removal	12/75	1/10	1.600	0.23–11.03	0.633
Deep infection	3/75	0/10	1.013	0.07–18.32	0.993
Superficial infection	0/75	0/10	0.145	0.003–6.93	0.329
Skin necrosis	1/75	0/10	0.434	0.02–10.018	0.602
Nerve injury	1/75	0/10	0.434	0.02–10.01	0.602
Double screw					
Hardware related pain & removal	6/83	3/22	0.530	0.14–1.95	0.340
Deep infection	2/83	1/22	0.530	0.05–5.58	0.597
Superficial infection	1/83	1/22	0.265	0.02–4.07	0.341
Skin necrosis	0/83	0/22	0.274	0.01–13.43	0.514
Nerve injury	4/83	1/22	1.060	0.12–9.01	0.957

incision types displayed no significant difference in either the single or double screw groups ($p > 0.05$). These findings are summarized in Table 4.

4. Discussion

Calcaneal osteotomy is one of the most common operative procedures used for restoration of the hindfoot alignment [2,4,5]. Outcomes from this procedure are overwhelmingly positive, with nonunion being a rare occurrence [7]. The high vascularity of the calcaneus, along with its largely cancellous bone structure, makes it very favorable for achieving adequate and rapid bone healing. Thus, overt concern for a fixation construct that minimizes nonunion is likely unwarranted. These characteristics contribute to the wide variability in calcaneal osteotomy fixation methods including the number of screws used — however, majority of studies utilize double screw fixation [7]. While there is minimal concern for nonunion, the primary rationale for the addition of a second screw in screw fixation is to counteract rotational forces that tutilize the fixation point of a single screw as a fulcrum or pivot for free rotational motion. However, this effect is largely theoretical as such findings have been limited to biomechanical studies [8]. Thus, the use of double screw fixation is partly based in theoretical risks that are not clinically appreciable, increasing operative time as well as economic costs [14].

Screw fixation is the most common method of fixation in calcaneal osteotomy [9]. However, despite its prevalence, there are very few reports in the literature comparing outcomes and complications between single screw and double screw calcaneal osteotomy fixation. The present study is the first to explore this topic. We found no significant difference in complications (hardware related pain, hardware removal, nerve injury, infection rate, and skin complications) between single and double screw fixation, using screws of identical size (6.5 mm diameter screws were used in both single screw and double screw techniques) (Table 2). Lucas et al. found less hardware related symptoms in patients undergoing calcaneal osteotomy fixation with two smaller (4.5 mm) diameter screws compared to one larger (7.0 mm) diameter screw [9], and Sayres et al. reported similar findings [11]. In our study as well as the two aforementioned, there was no difference in union rates when comparing single and double screw fixation. The reduced cost [9] and operating time associated with a single screw make it favorable to double screw fixation in otherwise equivalent situations. Additionally, prior biomechanical investigation suggests screw size and type to have minimal impact with regard to stability and union rate of calcaneal osteotomies [15]. Our study supports that larger screw diameter tends to increase the risk of complications compared to using multiple smaller screws in fixation of calcaneal osteotomies.

Hardware-related pain and need for hardware removal are important outcomes in calcaneal osteotomy follow-up. Previous studies have highlighted the impact of screw type (headed versus headless) on this particular outcome with headed screws carrying a greater risk for negative outcomes. Abbasian et al. found headed screws to have a higher rate of hardware removal due to pain (47%, 8/17) than headless screws (11%, 2/18) [7]. Our study supports these findings with a lower rate of hardware related symptoms and necessity for hardware removal being associated with headless screw fixation in both single and double screw fixation. Twenty-four percent (18/75) of patients with headed screw fixation and 3.5% (4/115) of patients with headless screw fixation required hardware removal secondary to hardware-related pain (Table 3). Although these hardware removal rates are lower than those reported by Abbasian et al., we believe these rates are more accurate due to the larger sample size and thus increased power of our study.

We did not observe significant differences in complication rates across incision types — short incision versus extended incision (Table 4). This corroborates the prior work by Kendal et al., which found incision size to have no appreciable effect on complications in patients undergoing calcaneal osteotomy [16]. However, it should be noted the present study included a significantly larger number of cases than this prior paper (190 vs. 81).

This study has limitations. First, due to its retrospective design, chart review had to be performed to extract the necessary data. Therefore it is possible that diagnosis thresholds and documentation patterns among physicians could have led to inconsistencies in the data collected. Also, while the results showed no difference in union and complication rates between the one and two screw groups, the authors were unable to collect clinical outcome scores on all patients and concede this could have allowed for the oversight of subtle clinical differences. Additionally, due to a low number of isolated calcaneal osteotomies, surgeries in which other procedures were performed were included, thus adding a potential confounding variable. Finally, both lateral and medial slide calcaneal osteotomies were included.

5. Conclusion

In conclusion, our study found the number of screws (one vs. two) used in fixation or type of incision to have no significant impact on union rate and on complications in patients undergoing calcaneal osteotomy. However, use of headless screws was

associated with a significantly decreased incidence of hardware related pain and subsequent hardware removal surgery.

Conflict of interest

The authors declare that there are no conflicts of interest.

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