

Minimally invasive manipulative reduction with poking k-wire fixation in the treatment of various types of calcaneal fractures

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Abstract. – OBJECTIVE: The aim of this study is to investigate the safety and clinical efficacy of minimally invasive manipulative reduction with poking k-wire fixation in the treatment of various types of calcaneal fractures.

PATIENTS AND METHODS: Between July 2012 and July 2014, a prospective parallel controlled study was conducted on 96 patients with closed calcaneal fractures who were admitted to our institution. These patients were randomly divided into two groups, with 48 in each group. Patients in plate group were treated using open reduction and internal fixation, whereas those of manipulation group were treated with minimally invasive manipulative reduction with poking k-wire fixation. All patients were followed up for six months to assess the postoperative recovery and complications. Kerr's scale was adopted to evaluate the functional recovery of fractured calcaneus.

RESULTS: A mean healing duration of 9.48 ± 1.92 weeks was achieved in patients of plate group compared with a healing duration of 9.35 ± 1.66 weeks in those of manipulation group, with no statistical significance ($p > 0.05$). Complications occurred in 20 cases in plate group versus in seven cases in manipulation group with significant difference ($p < 0.05$). As for Sanders type II fracture, among patients with compression fracture and tongue type fracture, > 70% of patients achieved with excellent and good outcomes in both groups with no significant difference in clinical efficacy ($p > 0.05$). The rate of excellent and good outcomes in Sanders type III compression fractures was lower in manipulation group than in plate group ($p < 0.05$). As for Sanders type II fractures, the Kerr's score of tongue type fractures in manipulation group was higher than that in plate group, and comparison within manipulation group showed that the score of tongue type fractures was significantly higher than that of compression fractures ($p < 0.05$). However, as for Sanders type III fractures,

the score of tongue type fractures in manipulation group was significantly higher than that in plate group, and the score of compression fractures in plate group was significantly higher than that in manipulation group ($p < 0.05$).

CONCLUSIONS: Minimally invasive manipulative reduction with poking k-wire fixation is suitable for the treatment of Sanders type II tongue type and compression calcaneal fractures, as well as the treatment of Sanders type III tongue type fractures with several advantages, including easy operation, lower cost, fewer complications and favorable recovery.

Key Words:

Calcaneal fracture, Poking technique, Minimally invasive manipulative reduction with k-wire fixation.

Introduction

Calcaneal fracture is a common fracture of tarsal bones. As majority are intra-articular fractures, which will increase calcaneal width, involve the subtalar joint surface and decrease the Böhler's angle, and improper treatment can result in unfavorable outcomes or disability^{1,2}. Calcaneal fracture is a complex fracture, and currently, different type of fracture is treated from different approach, resulting in unpredictable outcomes. Therefore, calcaneal fracture is considered as a big challenge in the clinical treatment of fractures³. Manipulative reduction with internal fixation, as a minimally invasive technique, has been shown to result in less soft tissue injuries and less complications⁴. In the present study, a prospective parallel controlled study was conducted on 96 patients with closed calcaneal fractures who were admitted to our institution

between July 2012 and July 2014. According to Essex-Lopresti classification and Sanders classification for fractures, minimally invasive manipulative reduction with percutaneous poking K-wire fixation was investigated for its clinical efficacy and safety in the treatment of various types of calcaneal fractures⁵.

Patients and Methods

Inclusion Criteria

The inclusion criteria were as follows: cases conforming to the diagnostic criteria for calcaneal fracture⁶; closed fracture within two weeks; CT scan and X-ray examination confirmed Sanders II and Sanders III fractures or compression fracture and tongue type fracture classified by Essex-Lopresti system. Patients of age < 18 years or > 65 years, simple non-displaced calcaneal fractures, severe collapsed comminuted fractures, patients with severe liver and kidney disorders, psychiatric disorders or accompanied with other severe trauma and open fractures were excluded from the study. Informed consent was obtained from all eligible patients.

General Information

Between July 2012 and July 2014, a prospective parallel controlled study was conducted in 96 patients with closed calcaneal fracture admitted at our institution. These patients were randomly divided into two groups, 48 for each group. The plate group consisted of 38 males and 10 females with a total of 58 fractured feet. The mean age was 43.25 ± 4.26 years (ranging from 22 to 64 years) and mean body weight was 60.44 ± 5.23 kg. Compression fractures were confirmed in 37 feet and tongue type fractures in 21 feet according to Essex-Lopresti 15 system; Sanders II fractures were found in 34 feet and Sanders type III fractures were found in 24 feet. Manipulation group comprised of 36 males and 12 females with a total of 22 fractured feet. The mean age was 45.12 ± 5.16 years (ranging from 20 to 65 years) and mean body weight was 62.34 ± 4.21 kg. Of these patients, compression fractures were confirmed in 40 feet, tongue type fractures were confirmed in 22 feet, Sanders type II fractures were confirmed in 37 feet and Sanders type III fractures were confirmed in 25 feet. No significant differences were observed in terms of age, body weight, gender, history of diseases and clinical course of the disease between groups ($p > 0.05$).

Treatment

Plate group

This group of patients were treated with open reduction and internal fixation. The surgery was performed with patients being in lateral decubitus position under spinal anesthesia. After sterilization, a lateral L-shaped incision was made on the affected foot followed by fracture reduction. Bone grafting was performed if required. Internal fixation was performed using a calcaneal plate (Smith & Nephew, Memphis, TN, USA). Subsequently, a drainage tube was placed, incision was then closed and cast immobilization was performed. Postoperative prophylactic antibiotics were administered for 24 hours, sutures were removed at the 3rd postoperative week; cast was removed and joint exercise begun at the 4th postoperative week, and weight-bearing walk was initialized at 8-12th postoperative week.

Manipulation Group

Patients in manipulation group were treated with minimally invasive manipulative reduction using poking K-wire fixation. The procedures were performed with the patients being in lateral decubitus position under spinal anesthesia. Guided by fluoroscopy, the first K-wire was inserted from the superior external side of the calcaneal tuberosity and advanced to the forefoot without crossing the fracture line. With the forefoot in dorsiflexion position, the K-wire was pulled and poked towards the plantar, and reduction was performed to allow for calcaneal inversion and eversion, as well as flexion and extension of the ankle. Fluoroscopy confirmed that Böhler's angle was restored within the range of 25°-40° and the length and height of the calcaneus were restored. The K-wire was inserted into the talus after restoring the subtalar joint surface. A second K-wire was inserted at 1-2 cm inferior to the first K-wire and in the direction parallel to the inferior of the calcaneus, for fracture fragments stabilization as well as fixation and support between the talus and the calcaneus. The heel was squeezed to reduce the calcaneal width. Finally, the fixation was completed by inserting a third K-wire from the posterior of the calcaneus, traversing the fractured fragments of the subtalar joint and reaching the tarsal bones. Lateral fluoroscopic view demonstrated that the three K-wires formed a \neq structure. The external end of K-wire was trimmed to 1cm. After routine sterilization, the insertion portal was wrapped with al-

Table I. Safety evaluation.

Group	Plate group	Manipulation group	<i>t</i>	χ^2	<i>p</i>	
Fracture healing duration (weeks)	(9.48 ± 1.92)	(9.35 ± 1.66)	0.397	--	0.346	
Complications (n)	Unstable internal fixation	0	4	--	16.714	0.000
	Neural and vascular injuries	5	0			
	Unfavorable healing	16	2			

cohol gauze followed by sterile dressing covering. Exercise of the affected foot was commenced on the next day with non-weight-bearing functional exercises. K-wires were removed and partial weight-bearing exercise was initiated at the 8th postoperative week. Weight-bearing walk without crutches were performed at the 12th postoperative week.

Outcome Measures and Efficacy Evaluation

Postoperative follow-up was conducted to record and evaluate the fracture healing progression, stability of internal fixation, neural damage and complications. At six months postoperatively, patients' the ability to walk or work, and pain level were assessed by Kerr scales. A score of 85 points is defined as excellent, 71-85 as good, 51-70 as fair and < 50 as poor.

Statistical Analysis

Statistical analysis was performed using SPSS software version 18.0 (SPSS Inc., Chicago, IL, USA). Qualitative data were analysed using χ^2 test whereas quantitative data were analyzed using *t*-test. *p* < 0.05 was considered statistically significant.

Results

Adverse Reactions and Safety Evaluation

A 24-week follow-up showed that healing was achieved in both groups during 8-12 weeks postoperatively, with a mean healing duration of 9.48 ± 1.92 weeks in plate group and 9.35 ± 1.66 weeks in manipulation group, with no statistical significance (*p* > 0.05). In plate group, sural nerve injury occurred in 5 cases and skin edge necrosis at incision site occurred in 16 cases. In

manipulation group, retreated k-wire was observed in 4 cases and pin tract infection was found in 2 cases, and no neural or vascular injury was observed. Significant difference was observed in the incidence of complications between groups (*p* < 0.05) (Table I).

Outcome Evaluation

As for Sanders type II fracture, an excellent and good outcomes rate of > 70% was achieved in patients with compression fracture and tongue type fracture in both groups with no significant difference in clinical efficacy between groups (*p* > 0.05). However, the percentage of patients with excellent and good outcomes was significantly higher in tongue type fracture than that in compression fracture, with a rate of > 80% achieved in Sanders type III tongue type fractures. For compression fractures, the rate of excellent and good outcomes was significantly lower in manipulation group than in plate group (*p* < 0.05) (Tables II and III).

Kerr's Score

The outcomes of Sanders type II fractures were evaluated by comprehensively assessing the pain, the ability to work and the ability to walk according to Kerr's scale. The results demonstrated that the scores of tongue type fractures in manipulation group were higher than those in plate group. The comparison within manipulation group showed that scores of tongue type fractures were significantly higher than those of compression fractures (*p* < 0.05). However, as for Sanders type III fracture, scores of tongue type fractures in manipulation group were significantly higher than those of plate group, whereas scores of compression fractures in plate group were significantly higher than those of manipulation group (*p* < 0.05) (Table IV and V).

Table II. Outcome evaluation for Sanders type II fractures classified by Essex-Lopresti system.

Group	Tongue type fracture					Rate of excellent and good outcomes (%)	Compression fracture				Rate of excellent and good outcomes (%)	
	Foot (n)	Excellent	Good	Fair	Poor		Excellent	Good	Fair	Poor		
Manipulation group	37	8	2	2	0	83.33	11	7	5	2	72.00	
Plate group	34	6	2	1	1	80.00	12	6	4	2	75.00	
χ^2, P		0.105, 0.746						0.177, 0.674				

Discussion

The majority of calcaneal fractures are high-energy injuries and accompanied with various degrees of soft tissue damages. Accurate evaluation of accompanied injuries and soft tissue conditions is a key factor influencing the surgical effect of open reduction with internal fixation, directly determining the optimal timing of the operation procedures, as well as affecting the healing progression of surgical incision and postoperative recovery⁷⁻⁹. The major complication associated with open reduction is wound complication. As the surgical techniques advance, operation time and the quality of materials for internal fixation, success rate of the surgery have been improved. However, the prevalence of complications such as plate exposure and skin edge necrosis is still high and, thereby, tackling this issue has become the focus of clinical studies¹⁰⁻¹³. In recent years minimally invasive manipulative technique has become a widely employed surgical approach. With the defined indications for the surgery and proficiency in surgical skills, minimally invasive approach has been reported to result in smaller incision, easier to recover and fewer complications compared to the open reduc-

tion with internal fixation¹⁴⁻¹⁸. As different type of fractures requires different reduction approach, the clinical efficacy of minimally invasive manipulative reduction has been controversial. In the present study a parallel controlled study was conducted on 96 patients with closed calcaneal fractures who were admitted to our institution between July 2012 and July 2014. According to Essex-Lopresti classification and Sanders classification for fractures, minimally invasive manipulative reduction with percutaneous poking K-wire fixation was investigated for its clinical efficacy and safety in the treatment of various types of calcaneal fractures, as well as for a prospective exploration of specific reduction techniques for particular types of calcaneous fracture.

In the present study types of fractures have been classified using Sanders classification and Essex-Lopresti classification system. Sanders classification system defines the type of fracture based on the injuries of posterior articular facet of the calcaneus detected by CT examination, whereas Essex-Lopresti system classifies fracture type according to the entire morphology of the calcaneus upon radiographic study¹⁹⁻²³. Majorities of studies have employed a single classifica-

Table III. Outcome evaluation in Sanders type III fractures classified by Essex-Lopresti system.

Group	Tongue type fracture					Rate of excellent and good outcomes (%)	Compression fracture				Rate of excellent and good outcomes (%)	
	Foot (n)	Excellent	Good	Fair	Poor		Excellent	Good	Fair	Poor		
Manipulation group	25	5	4	1	0	90.00	3	2	8	2	33.33	
Plate group	24	4	4	2	1	80.00	8	3	1	1	84.62	
χ^2, P		1.066, 0.302						7.702, 0.005				

Table IV. Kerr's score in Sanders type II classified by Essex-Lopresti system.

Group		Number of foot	Ability to work	Pain	Ability to walk	Ability to assisted walk	Total score
Plate group	Compression fracture	24	22.19±3.47	27.19±1.21	20.62±0.72	13.33±1.62	83.33±7.02
	Tongue type fracture	10	21.64±1.44	26.98±1.92	20.25±0.97	12.87±1.21	81.74±5.54
Manipulation group	Compression fracture	25	21.74±1.63	28.39±1.99	20.59±0.78	13.41±1.25	84.13±5.65
	Tongue type fracture	12	24.53±1.47	32.97±2.33	22.08±1.54	12.94±1.74	92.52±7.08
vs.	<i>t, p</i>	--	0.481, 0.317	0.386, 0.351	1.231, 0.114	0.806, 0.213	0.636, 0.264
vs.	<i>t, p</i>	--	0.585, 0.281	2.537, 0.007	0.140, 0.445	0.194, 0.423	0.440, 0.331
vs.	<i>t, p</i>	--	4.633, 0.000	6.491, 0.000	3.251, 0.000	0.107, 0.458	3.913, 0.000
vs.	<i>t, p</i>	--	5.023, 0.000	6.202, 0.000	3.934, 0.000	0.941, 0.177	3.894, 0.000

Table V. Kerr's score in Sanders type III classified by Essex-Lopresti system.

Group		Number of foot	Ability to work	Pain	Ability to walk	Ability to assisted walk	Total score
Plate group	Compression fracture	13	23.23±2.42	32.21±1.53	22.53±1.86	13.18±2.07	91.15±7.88
	Tongue type fracture	11	19.34±1.32	25.43±1.58	20.51±2.03	12.22±2.44	77.50±7.73
Manipulation group	Compression fracture	15	20.52±2.31	28.72±1.26	19.49±1.88	14.04±1.57	82.77±7.02
	Tongue type fracture	10	22.42±1.68	31.87±1.92	22.11±2.17	13.51±2.02	89.91±7.79
vs.	<i>t, p</i>	--	4.756, 0.000	10.657, 0.000	2.543, 0.009	1.043, 0.154	4.265, 0.000
vs.	<i>t, p</i>	--	3.028, 0.003	6.620, 0.000	4.288, 0.000	1.248, 0.112	2.977, 0.003
vs.	<i>t, p</i>	--	4.695, 0.000	8.426, 0.000	1.746, 0.048	1.312, 0.103	3.661, 0.001
vs.	<i>t, p</i>	--	2.231, 0.018	4.971, 0.000	3.211, 0.002	0.738, 0.234	2.386, 0.013

tion system to investigate the clinical indications and efficacy of manipulative reduction or open reduction with internal fixation. However, the use of the two classification systems allows for more detailed and comprehensive studies. Here, a comprehensive study using both Sanders and Essex-Lopresti classification systems was performed to determine and define displaced fracture fragments on the posterior articular facet of the calcaneus as well as the morphology of fracture lines. This approach enables more accurate and comprehensive determination of clinical indications of calcaneal fracture and the proper choice of treatment. The results of this work showed that healing was achieved in both groups during 8-12 weeks postoperatively. In plate group, sural nerve injury occurred in 5 cases and skin edge necrosis at incision site occurred in 16 cases. In manipulation group, retreated k-wire was observed in 4 cases and pin tract infection was found in 2 cases, and no neural or vascular injury was observed. Significant difference was observed in the incidence of complications between groups ($p < 0.05$), indicating that lower incidence of adverse reactions and surgical compli-

cations was achieved using minimally manipulative reduction with poking k-wire reduction. Outcome assessment demonstrated that among the patients with Sanders type III compression fractures, the percentage of those with excellent and good outcomes was lower in manipulation group than in plate group, indicating that open reduction with internal fixation is appropriate for the treatment of Sanders type III compression fracture. Comprehensive evaluation of the ability to work or walk, and pain level in Sanders type II fractures based on Kerr's scale showed that the score of tongue type fractures in manipulation group was higher than that in plate group. In addition, study within manipulation group demonstrated that the score of tongue type fractures was higher than that of compression fractures, suggesting that minimally invasive manipulative reduction with poking k-wire fixation is suitable for the treatment of Sanders type II tongue type fracture, with better clinical outcomes and yet less functional recovery and lower incidence of complications. Furthermore, the score of patients with Sanders type III tongue type fractures in manipulation group was higher than that in plate

group, whereas the score of patients with compression fractures in plate group was higher than that in manipulation group. All these results suggested that minimally invasive manipulation is appropriate for the treatment of Sanders type III tongue type fracture, whereas open reduction with internal fixation is suitable for managing the compression fracture.

Conclusions

Different type of calcaneal fracture should be treated with different reduction approach. Fracture type should be accurately defined and evaluated according to CT and radiographic imaging findings, as well as the extent of injuries at affected area so as to narrow down surgical indications and employ the advantages of minimally invasive techniques, and thereby select the effective surgical approaches. Manipulative reduction with poking k-wire fixation is suitable for the treatment of Sanders type II tongue type fracture and compression fracture as well as Sanders type III tongue type fracture, with lower cost, rapid recovery and smaller wound. This approach can be employed in clinical practice when surgical indications are met.

Conflict of Interest

The Authors declare that they have no conflict of interests.

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