Am J Transl Res 2021;13(5):5329-5335
www.ajtr.org /ISSN:1943-8141/AJTR0128975

Original Article

Impact of percutaneous poking reduction combined with minimally invasive plate internal fixation on foot function and complications of patients with Sanders type II and III calcaneal fractures

Libin Jiao[1*], Hua Li[2*], Tingkai Liao[3], Zengwu Han[4], Hongbin Wu[5], Lei Jiang[6]

[1]Department of Orthopedics, Tian's Hospital of Jinhua City, Jinhua, Zhejiang Province, China; [2]Fifth Department of Surgery, The People's Hospital of Penglai, Yantai, Shandong Province, China; [3]Department of Traumatology and Orthopedics, The People's Hospital of Linqing, Liaocheng, Shandong Province, China; [4]Second Department of Orthopedics, Gucheng County Hospital of Hebei Province, Hengshui, Hebei Province, China; [5]Second Department of Orthopedics, Changle County Hospital of Traditional Chinese Medicine, Weifang, Shandong Province, China; [6]First Department of Traumatology and Orthopedics, Zaozhuang Mining Group Zaozhuang Hospital, Zaozhuang, Shandong Province, China. [*]Equal contributors and co-first authors.

Received December 25, 2020; Accepted February 1, 2021; Epub May 15, 2021; Published May 30, 2021

Abstract: Objective: To investigate the impact of percutaneous poking reduction (PPR) combined with minimally invasive plate internal fixation on foot function and complications of Sanders type II and III calcaneal fractures (CFs). Methods: In this prospective study, 76 patients with Sanders type II and III CFs were randomly divided into the control group (n=38, "L" incision open reduction and plate internal fixation) and the study group (n=38, PPR combined with minimally invasive plate internal fixation (MIPIF)). The operation related indexes, skin necrosis rate, Gissane angle, Bohler angle, calcaneal height and ankle-hindfoot score before and after the operation were compared between the two groups. Complications of the two groups were recorded. Results: Compared with the control group, the operation time of the study group was significantly prolonged, but the intraoperative blood loss was significantly reduced, and the fracture healing time and hospitalization time were significantly shortened (P<0.05). The skin necrosis rate of the study group was slightly lower than that of the control group without statistical significance (P>0.05). The Gissane angle, Bohler angle and calcaneal height of the two groups increased 6 months after the operation, and the changes in the study group were more obvious than those in the control group (P<0.05). Six months after the operation, the ankle-hindfoot scores of the two groups significantly increased, and the changes of the study group were more significant than that of the control group (P<0.05). The total incidence of postoperative complications in the study group was significantly lower than that in the control group (P<0.05). Conclusion: PPR combined with MIPIF can significantly promote the healing of Sanders type II and III CFs and the recovery of the Gissane angle and Bohler angle, effectively improve the foot function of patients and induce fewer complications, which is worthy of clinical promotion.

Keywords: Percutaneous poking reduction combined with minimally invasive plate internal fixation, calcaneal fractures, foot function, complications

Introduction

More than half of the calcaneal fractures (CFs) are intra-articular fractures, mostly caused by falling from high places. Affected by the impact of landing with heels, the injury is often more serious, and the heel pain is often obvious, and the foot movement function is limited [1, 2]. At present, there is no unified consensus on the treatment of CFs. Plate internal fixation and lateral calcaneal open reduction are common surgical methods for the treatment of foot fractures, but they may cause various postoperative complications, and the recovery of patients is limited [3, 4]. Some scholars believe that open anatomical reduction and restoration of calcaneal anatomical morphology are the keys to the treatment of CFs [5]. However, the lateral

calcaneal skin is relatively weak, and there are many wound complications after open reduction and internal fixation [5]. Percutaneous poking reduction (PPR) is the earliest minimally invasive treatment method applied to CFs, such as PPR combined with Kirschner wire internal fixation and PPR combined with cannulated screw internal fixation. But the biomechanical strength of Kirschner wire internal fixation and cannulated screw internal fixation is not as good as that of plate internal fixation, and there are some defects such as loss of postoperative reduction and poor joint surface reduction [6]. Cui et al. tried to use PPR combined with minimally invasive plate internal fixation (MIPIF) to treat CFs and found that the postoperative complications were fewer, and the patients recovered faster after the operation [7]. CFs can shorten the length of the calcaneus and decrease the height of the calcaneus. The vertical compressive stress can affect the flatness of the subtalar joint, resulting in an abnormal Gissane angle on the axial side of the calcaneus, which leads to the reduction or even disappearance of the Bohler angle [8, 9]. Therefore, the Gissane angle and Bohler angle should be taken as important indicators for recovery after CF surgery. This study mainly discussed the impact of PPR combined with MIPIF on the Gissane angle, Bohler angle and foot function of Sanders type II and III CF patients and analyzed the postoperative complications.

Materials and methods

General information

In this prospective study, 76 patients with Sanders type II and III CFs in our hospital from December 2018 to February 2020 were randomly divided into the study group and the control group, each group containing 38 patients.

The inclusion criteria were: 18-60 years old; Diagnosed as Sanders type II and III fresh closed CFs according to Paley classification [10]. Unilateral fractures; Without abnormal limb function before fracture; Informed of the consent of this study. The exclusion criteria were: a history of ankle trauma; pathological or open fractures; bilateral CFs; old CFs; coagulation dysfunction; participating in other projects. This study was approved by the Ethics Committee of our hospital.

Methods

Both groups were operated on under continuous epidural anesthesia.

The control group received “L” incision open reduction and plate internal fixation. From the lateral calcaneal skin along the foot dorsum and plantar skin junction, an “L” shaped incision was made to the bone surface. The tissue flap was separated and lifted. The fibula tendon was pulled to expose the fracture and calcaneal joint surface completely. The foot deformity was corrected, and the fracture was reduced to the anatomical position with Kirschner wire (2.5 mm) after satisfactory fixation. The steel plate was used for fixation. The rubber sheet was then placed at the back end of the incision, and the cut was sutured and bound.

The study group received PPR combined with MIPIF. Firstly, calcaneal traction was performed to correct the varus deformity. The ankle joint was plantar-flexed, and the Kirschner wire was inserted near the Achilles tendon. The position of the Kirschner wire was confirmed under the perspective of a C-arm X-ray machine. The poking reduction was then performed. The joint surface was slowly raised, and both sides of the calcaneus were continuously pressed. The Kirschner wire was used for temporary fixation to confirm the Gissane angle and Bohler angle. The recovery of varus deformity was observed. If the effect was not satisfactory, a poking reduction could be performed again. An incision was made on the lateral calcaneal skin. The skin was incised layer by layer to the periosteum. The soft tissue was peeled off, and the calcaneal locking plate was placed. The position of the plate was fixed with Kirschner wire. The rubber sheet was then placed at the back of the incision, and the cut was sutured and bound.

Outcome measures

Main outcome measures: (1) Gissane angle, Bohler angle and calcaneal height before and after the operation were compared between the two groups. Gissane angle refers to the angle formed by the anterior and posterior articular surface of the calcaneal talocalcaneal joint, with a normal value of 120°-145°. Bohler angle refers to the angle formed by the line between the anterior and posterior articular

Table 1. Comparison of baseline data between the two groups (n, $\bar{x}$ ± sd)

Index	Study group (n=38)	Control group (n=38)	χ^2/t	P
Gender (n)			0.213	0.645
Male	22	20		
Female	16	18		
Age (years)	44.4±4.9	45.3±5.3	0.769	0.445
BMI (kg/m^2)	23.10±3.05	23.37±2.54	0.419	0.676
Cause of fractures (n)			0.478	0.788
High-altitude falling	19	16		
Car accident injury	12	14		
Others	7	8		
Paley Classification (n)			0.844	0.358
Sanders type II	20	16		
Sanders type III	18	22		

Note: BMI: body mass index.

process of the calcaneus and the line between the calcaneal tubercle and the posterior articular process of the calcaneus, with a normal value of 25°-40°. (2) Ankle function before and after the operation was appraised with the ankle-hindfoot score developed by the American Orthopedic Foot and Ankle Society (AOFAS) [11]. The ankle-hindfoot score includes three items: function (50 points), pain (40 points) and alignment (10 points), with a total score of 100 points. Higher scores indicate better ankle function.

Secondary outcome measures: (1) The operation related indexes, such as the operation time, intraoperative blood loss, fracture healing time and hospitalization time, were compared between the two groups. (2) The skin necrosis rate was compared between the two groups. The skin necrosis rate = (skin necrosis cases/total cases) *100%. (3) The incidence of complications was compared between the two groups, such as delayed wound healing, wound infection and subtalar arthritis. Complication rate = (cases of complications/total cases) *100%.

Statistical analysis

SPSS 20.0 was used to analyze the data. Enumeration data were displayed as (n, %) and analyzed by the χ^2 test. Measurement data were displayed as mean ± standard deviation ($\bar{x}$ ± sd). The independent-samples t-test was adopted to compare the data between the two groups. The paired-samples t-test was adopted for comparison of the indexes before and after the operation. P<0.05 was considered significantly different.

Results

Baseline data

Baseline data such as gender, age, body mass index (BMI), cause of fractures, and Paley classification showed no significant difference (P>0.05) and were comparable between the two groups. See **Table 1**.

Operation related indexes

Compared with the control group, the operation time of the study group was significantly prolonged, but the intraoperative blood loss was significantly reduced, and the fracture healing time and hospitalization time were significantly shortened (P<0.05). See **Table 2**.

Skin necrosis rate

In this study, all 78 patients were successfully operated on for the first time. Three cases of skin necrosis occurred in the control group, with a skin necrosis rate of 7.89%. One case of skin necrosis occurred in the study group, with a skin necrosis rate of 2.63%. The skin necrosis rate of the study group was slightly lower than that of the control group, but showed no significant difference (P>0.05).

Gissane angle, Bohler angle and calcaneal height

The Gissane angle, Bohler angle and calcaneal height of the two groups increased 6 months after the operation, and the changes in the study group were more obvious (P<0.05). See **Table 3**; **Figures 1**, **2**.

Ankle-hindfoot score

The ankle-hindfoot score of the two groups both significantly increased 6 months after the operation, and the score of the study group was higher than that of the control group (P<0.05). See **Table 4**.

Table 2. Comparison of clinical related indexes between the two groups ($\bar{x}$ ± sd)

Index	Study group (n=38)	Control group (n=38)	t	P
Operation time (min)	85.69±10.94	64.94±8.70	9.151	<0.001
Intraoperative blood loss (mL)	30.04±5.58	67.90±8.30	23.335	<0.001
Fracture healing time (month)	3.65±0.93	4.21±1.20	2.274	0.026
Hospitalization time (d)	8.40±2.30	14.38±4.22	7.670	<0.001

Table 3. Comparison of the Gissane angle, Bohler angle and calcaneal height before and after the operation between the two groups ($\bar{x}$ ± sd)

Group	Time	Gissane angle (°)	Bohler angle (°)	Calcaneal height (mm)
Study group (n=38)	Before the operation	88.46±10.48	13.39±2.20	34.40±4.40
	Six months after the operation	130.90±11.27*,#	27.40±3.11*,#	45.50±4.95*,#
Control group (n=38)	Before the operation	89.19±9.73	13.84±2.94	35.11±5.20
	Six months after the operation	124.48±8.74*	24.29±3.04*	40.84±4.39*

Note: Compared with before intervention, *P<0.05; compared with the control group, #P<0.05.

Figure 1. A 50-year-old male patient with calcaneal fractures was injured by falling from a height of 2 meters with displacement greater than 2 mm, Sanders type II.

Figure 2. Lateral radiograph after the calcaneal fracture operation showed that Bohler angle was significantly improved compared with before operation.

Complications

The total complication rate of the study group was 2.63% (1 case of delayed wound healing), significantly lower than that of the control group (15.79%; 2 cases of delayed wound healing, 1 case of incision infection and 3 cases of subtalar arthritis; P<0.05). See **Table 5**.

Discussion

This prospective study compared the therapeutic effects of "L" incision open reduction and plate internal fixation (the control group) and PPR combined with MIPIF (the study group) on Sanders type II and III CFs. The results informed that intraoperative blood loss of the study group was significantly reduced, the fracture healing time and hospitalization time of the study group were significantly shortened, however, the skin necrosis rate of the study group was slightly lower than that of the control group, without significant difference, suggesting that PPR combined with MIPIF can significantly promote the healing

Table 4. Comparison of the ankle-hindfoot index scores before and after the operation between the two groups ($\bar{x}$ ± sd, score)

Group	Time	Function	Pain	Alignment
Study group (n=38)	Before the operation	33.39±5.50	20.05±4.33	4.40±1.10
	Six months after the operation	40.09±4.78*,#	32.68±3.80*,#	7.21±1.50*,#
Control group (n=38)	Before the operation	32.70±4.80	20.47±4.58	4.28±1.27
	Six months after the operation	36.87±4.69*	27.08±4.09*	6.03±1.19*

Note: Compared with before intervention, *P<0.05; compared with the control group, #P<0.05.

Table 5. Comparison of the postoperative complication rates between the two groups (n, %)

Group	Delayed wound healing	Incision infection	Subtalar arthritis	Total
Study group (n=38)	1 (2.63)	0 (0.00)	0 (0.00)	1 (2.63)
Control group (n=38)	2 (5.26)	1 (2.63)	3 (7.89)	6 (15.79)
χ^2	/	/	/	3.934
P	0.556	0.314	0.077	0.047

of Sanders type II and III CFs and shorten hospitalization time. He et al. reported that in the treatment of CFs, the skin necrosis rate of MIPIF was significantly lower than that of "L" incision open reduction and plate internal fixation [12]. The reason for no statistical significance in the skin necrosis rate of this study may be that the sample size is too small, and the number of postoperative skin necrosis cases is fewer.

Anatomic reduction of the articular surface fractures and recovery of the calcaneus's overall shape and related geometric parameters, such as the Gissane angle and Bohler angle, are the principles of anatomical reconstruction after CF surgery. The key of CF reduction is the restoration of the Gissane angle and Bohler angle [13-15]. De Boer et al. found that the recovery of the Gissane angle and Bohler angle after CF surgery was the main influencing factor of the ankle-hindfoot score of postoperative patients, which confirmed that the recovery of the Gissane angle and Bohler angle was the important parameters of the evaluation of CF surgery [16]. The results of this study informed that the Gissane angle, Bohler angle and calcaneal height of the two groups increased 6 months after the operation, and the changes in the study group were more significant. The results suggest that compared with "L" incision open reduction and plate internal fixation, PPR combined with MIPIF is more helpful to the recovery of the Gissane angle and Bohler angle in Sanders type II and III CF patients. Our findings are consistent with the study by Wang et al. [17]. Their study also found that for patients with CFs, the recovery of the Gissane angle and Bohler angle is closer to the normal range after PPR combined with MIPIF.

The ankle-hindfoot score is a special scoring system developed by AOFAS to evaluate foot function [18]. The results of this study showed that the ankle-hindfoot scores (function, pain, alignment) of the two groups both increased significantly 6 months after the operation, and the score of the study group was higher than that of the control group, indicating that compared with the "L" incision open reduction and plate internal fixation, PPR combined with MIPIF has a more obvious effect on improving the postoperative foot function of Sanders type II and III CFs. Chen et al. also pointed out that PPR combined with MIPIF could significantly improve the foot function of patients with CFs [19]. This is because after the MIPIF treatment, the Gissane angle and Bohler angle of patients can recover better and return to a normal state, and the overall shape of the calcaneus is well reduced. Therefore, the impact on foot function is smaller and does not affect patients' normal movement [20, 21]. The incidence of postoperative complications in the study group was significantly lower than that in the control group, which is consistent with the results reported by Clare et al. [22]. Their study found that the incidence of skin edge necrosis and soft tissue infection in patients after open reduction and plate internal fixation could be as high as 25%, of which about 21% of patients need to undergo a second surgery, while PPR combined with MIPIF could significantly reduce the risk of complications. However, this study also has the

shortcomings of a small sample size. Besides, the postoperative follow-up time is not long enough. The impact of PPR combined with MIPIF on long-term foot function and quality of life of Sanders type II and III CF patients still needs deeper investigation using a long-term follow-up study of a larger sample size.

To conclude, PPR combined with MIPIF can significantly promote the healing of Sanders type II and III CFs and the recovery of the Gissane angle and Bohler angle, effectively improve the foot function of patients and induce fewer complications.

Disclosure of conflict of interest

None.

Address correspondence to: Lei Jiang, First Department of Traumatology and Orthopedics, Zaozhuang Mining Group Zaozhuang Hospital, No. 188 Shengli Middle Road, Shizhong District, Zaozhuang 277101, Shandong Province, China. Tel: +86-0632-4071665; E-mail: jianglei5g6h@163.com

References

[1] Tsubone T, Toba N, Tomoki U, Arakawa D, Iiyama T, Hara N, Matsuo T and Fukuda F. Prediction of fracture lines of the calcaneus using a three-dimensional finite element model. J Orthop Res 2019; 37: 483-489.

[2] Rao K, Dibbern K, Day M, Glass N, Marsh JL and Anderson DD. Correlation of fracture energy with sanders classification and post-traumatic osteoarthritis after displaced intra-articular calcaneus fractures. J Orthop Trauma 2019; 33: 261-266.

[3] Yang B, Wang DC, Zhang XG and Wang ZW. Improved anatomical locking plate internal fixation through tarsal sinus incision in treating sanders III-IV calcaneal fractures. Zhongguo Gu Shang 2018; 31: 599-603.

[4] Scott AT, Pacholke DA and Hamid KS. Radiographic and CT assessment of reduction of calcaneus fractures using a limited sinus tarsi incision. Foot Ankle Int 2016; 37: 950-957.

[5] Wei N, Zhou Y, Chang W, Zhang Y and Chen W. Displaced intra-articular calcaneal fractures: classification and treatment. Orthopedics 2017; 40: e921-e929.

[6] Costa ML, Achten J, Rangan A, Lamb SE and Parsons NR. Percutaneous fixation with kirschner wires versus volar locking-plate fixation in adults with dorsally displaced fracture of distal radius: five-year follow-up of a randomized controlled trial. Bone Joint J 2019; 101-B: 978-983.

[7] Cui ST, Liu ZZ, Tang B, Chen GX and Wang ZZ. Closed reduction and internal fixation versus transtarsal sinus small incision internal fixation for sanders type II calcaneal fractures. Zhongguo Gu Shang 2019; 32: 448-453.

[8] Zhang G, Ding S and Ruan Z. Minimally invasive treatment of calcaneal fracture. J Int Med Res 2019; 47: 3946-3954.

[9] Peng Y, Liu J, Zhang G, Ji X, Zhang W, Zhang L and Tang P. Reduction and functional outcome of open reduction plate fixation versus minimally invasive reduction with percutaneous screw fixation for displaced calcaneus fracture: a retrospective study. J Orthop Surg Res 2019; 14: 124.

[10] Long C, Fang Y, Huang FG, Zhang H, Wang GL, Yang TF and Liu L. Sanders II-III calcaneal fractures fixed with locking plate in elderly patients. Chin J Traumatol 2016; 19: 164-167.

[11] Vosoughi AR, Roustaei N and Mahdaviazad H. American orthopaedic foot and ankle society ankle-hindfoot scale: a cross-cultural adaptation and validation study from Iran. Foot Ankle Surg 2018; 24: 219-223.

[12] He XY, Wang CQ and Zhou ZP. Clinical efficacy of cannulated screw fixation with percutaneous poking reduction for the treatment of calcaneal fracture. Zhongguo Gu Shang 2016; 29: 421-423.

[13] Félix GC, Matias MS, Lira RCA, Matias NS, de Sousa CJD and Pinto Neto LH. Radiographic analysis of intra-articular fractures of the calcaneus in patients undergoing minimally invasive surgical treatment in a tertiary hospital. Rev Bras Ortop (Sao Paulo) 2020; 55: 226-231.

[14] Gonzalez TA, Lucas RC, Miller TJ, Gitajn IL, Zurakowski D and Kwon JY. Posterior facet settling and changes in bohler's angle in operatively and nonoperatively treated calcaneus fractures. Foot Ankle Int 2015; 36: 1297-1309.

[15] Lee D, Yoo JH, Son DW and Kim DH. Is the bohler angle reliable for operative reduction of calcaneus fracture? J Orthop Sci 2019; 24: 521-525.

[16] De Boer AS, Van Lieshout EMM, Van Moolenbroek G, Den Hartog D and Verhofstad MHJ. The effect of time to post-operative weightbearing on functional and clinical outcomes in adults with a displaced intra-articular calcaneal fracture; a systematic review and pooled analysis. Injury 2018; 49: 743-752.

[17] Wang XJ, Su YX, Li L, Zhang ZH, Wei XC and Wei L. Percutaneous poking reduction and fixation versus open reduction and fixation in the treatment of displaced calcaneal fractures for Chi-

nese patients: a systematic review and meta-analysis. Chin J Traumatol 2016; 19: 362-367.
[18] Van Lieshout EM, De Boer AS, Meuffels DE, Den Hoed PT, Van der Vlies CH, Tuinebreijer WE and Verhofstad MH. American Orthopaedic Foot and Ankle Society (AOFAS) ankle-hindfoot score: a study protocol for the translation and validation of the dutch language version. BMJ Open 2017; 7: e012884.
[19] Chen H, Li YW, Jiang H, Zhang ZG and Lu BJ. Percutaneous poking reduction with bone grafting and limited internal fixation for the treatment of calcaneal fractures. Zhongguo Gu Shang 2017; 30: 1084-1090.
[20] Wu M, Guan J, Xiao Y, Wang Z, Chen X, Zhao Z, Zhang K and Zhu J. Application of three-dimensional printing technology for closed reduction and percutaneous cannulated screws fixation of displaced intraarticular calcaneus fractures. Zhongguo Xiu Fu Chong Jian Wai Ke Za Zhi 2017; 31: 1316-1321.
[21] Lai TC and Fleming JJ. Minimally invasive plate osteosynthesis for distal tibia fractures. Clin Podiatr Med Surg 2018; 35: 223-232.
[22] Clare MP and Crawford WS. Managing complications of calcaneus fractures. Foot Ankle Clin 2017; 22: 105-116.