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Original Article

Effects of full-threaded headless cannulated compression screws and anatomical plates on the efficacy, safety, and prognosis of patients with triplane fractures of the distal tibia

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Abstract: Objective: To compare the clinical efficacy, safety, and prognosis of full-threaded headless cannulated compression screws (HCCSs) and anatomical plates (APs) in the treatment of triplane fractures of the distal tibia. Methods: In this retrospective study, 74 patients with triplane fractures of the distal tibia treated in our hospital from April 2017 to March 2019 were selected as the research subjects. Among them, 38 patients receiving full-threaded HCCSs were assigned to the research group (RG), and the remaining 36 patients receiving APs were assigned to the control group (CG). The general indices, including operation, fracture healing, and ambulation times, efficacy, and complications were recorded and compared between the two groups. Visual analogue scale (VAS) was applied to assess pain, and a quality of life (QOL) survey was conducted at 6 months after surgery. Results: Compared with the CG, the operation time, fracture healing time, and ambulation time of the RG were significantly shortened ($P<0.05$). The proportion of patients with excellent and good outcomes and Mazur Scores in the RG were higher than those in the CG ($P<0.05$). The frequency of complications in the RG was lower than that in the CG ($P<0.05$). The preoperative VAS score did not exhibit significant differences between the two groups ($P<0.05$), but the scores in the RG at T1 and T2 were significantly lower than those in the CG ($P<0.001$). The QOL score in the RG (76.17±8.57) was also significantly higher than in the CG (71.54±8.02) ($P<0.05$). Conclusion: Full-threaded HCCSs are more effective and safer than APs and can effectively improve the prognosis of patients with triplane fractures of the distal tibia.

Keywords: Full-threaded headless cannulated compression screws, anatomical plate, triplane fractures of distal tibia, efficacy, prognosis

Introduction

Fractures in children and adolescents account for approximately 19.2% of lower extremity fractures, leading to significant mortality and morbidity [1]. Decruz et al. [2] have found that the incidence of tibial fracture is about 13/100,000, of which the distal tibial fractures account for 10%. Triplane fractures of the distal tibia, namely, distal tibial fractures in the horizontal, coronal, and sagittal planes, are a group of ankle injuries involving epiphyseal plate displacement and rupture due to external rotation caused by violent events, such as traffic accidents, collision, and high-altitude falls. These fractures are more common in teenagers aged 10-17 years old and are clinically rare and complex [3]. Due to the instability of the fracture end, complications such as malunion of the fracture end and joint stiffness are common if not treated properly. This is not conducive to the growth and development of teenagers, leading to walking difficulties and even lower limb dysfunction [4]. In recent years, open reduction and internal fixation have been the main treatment. Anatomical plate (AP) internal fixation is a relatively traditional method of internal fixation, and has achieved satisfactory results in clinical practice [5, 6]. AP is a new medical material based on the anatomical

structure of joints, but there are still many deficiencies due to severe surgical trauma [7]. Since the triplane fractures of the distal tibia occur in the metaphysis of the distal tibia, which is not fully matured, minimization of epiphyseal injury should be considered in the selection of treatment method [8]. Full-threaded headless cannulated compression screws (HCCSs) are an emerging minimally invasive surgical method that can be guided by precise positioning to avoid damage to surrounding tissues [9]. Compared with tension band steel wire fixation and partially threaded cannulated screws, full-threaded HCCSs are a more effective and less painful method for the treatment of medial malleolus fractures [10]. However, there are currently few reports on the use of full-threaded HCCSs in the treatment of triplane fractures of the distal tibia, thus it is impossible to accurately judge its effectiveness in the treatment of these fractures. This study compared the value of two different treatment methods, full-threaded HCCSs and APs, in the treatment of triplane fractures of the distal tibia to guide future clinical treatment of these fractures.

Materials and methods

Clinical data

A total of 74 patients with triplane fractures of the distal tibia treated in our hospital from April 2017 to August 2021 were retrospectively enrolled as the research subjects. Among them, 38 patients receiving full-threaded HCCSs (Cat. No 03.226.000, Depuy synthes, US) were assigned to the research group (RG), and the remaining 36 patients receiving APs (LCP Metaphyseal Plates 3.5, Depuy synthes, US) were assigned to the control group (CG). This study was approved by the Medical Ethics Committee of Affiliated Hospital of Hebei University of Engineering (approval number 2020[J]001-14).

Inclusion and exclusion criteria

Inclusion criteria: patients with a clear history of trauma and clinical manifestations of a fracture diagnosed as the triplane fracture of the distal tibia by imaging. Exclusion criteria: patients with pathological fractures; patients who had received fixation treatment before participating in the study; patients with low compliance with treatment; patients with surgical intolerance; patients with incomplete clinicopathological data; or patients who transferred from other hospitals.

Methods

Patients in the RG received the full-threaded HCCS fixation. After anesthesia, patients in the RG were placed in the supine position. An incision was made with the fracture end as the center, and the incision length extended to the ankle joint cavity to clean the fracture end and flush the joint cavity. The fracture was then examined under MRI (Somatom Force; Siemens Healthineers, German) and the position was temporarily maintained with 3-4 Kirschner wires. After fluoroscopy confirmation, a screw channel was established along the Kirshner wire position with a hollow drill. Next, a headless compression full-thread cannulated screw of appropriate length was selected and implanted along the guide wire to confirm the screw position, and the incision was sutured after confirming no loosening or displacement.

Patients in the CG were treated with the AP internal fixation. If the fracture displacement was not obvious, or after manual reduction, the position of the fracture end could be maintained by plaster, splint, continuous traction or other treatments until the fracture healed, and conservative treatment could be considered; but the possible complications caused by conservative treatment must be considered. An incision was made at the fracture site and extended to fully expose the fracture end. Then, the periosteum was removed, the anatomical structure was determined, and a steel plate of appropriate length was selected for fixation. All patients were given symptomatic treatment such as ibuprofen (B12200000028, Sino-American Tianjin SmithKline & French Laboratories) and aspirin (CAS No.: 50-78-2, Hubei Nordina Biotechnology Co., Ltd.) after surgery.

Outcome measures

The general indices, such as operation time, fracture healing time, and ambulation time, were compared between the two groups of patients. Efficacy evaluation: according to the patients' fracture healing status, the treatment outcomes were divided into three grades: excellent, good, and poor. Excellent was defined as

Table 1. Mazur scoring criteria (points)

	Pain (50)	Mobility (30)	Walking status (20)
Excellent (>92)	None	Freely	Normal
Good (85-92)	Mild	Unable to exercise strenuously	Normal
Fair (65-84)	When moving	Need external help	Slow
Poor (<65)	All the time	Unable to move	Limp

Table 2. Comparison of general data between the two groups [n (%)]

General data	RG (n=38)	CG (n=36)	*t* or χ^2	*P*
Age (years old)	14.19±2.35	14.67±2.42	0.866	0.390
Gender			0.452	0.501
Male	23 (60.53)	19 (52.78)		
Female	15 (39.47)	17 (47.22)		
Fracture site			0.542	0.462
Left lower limb	20 (52.63)	22 (61.11)		
Right lower limb	18 (47.37)	14 (38.89)		
Cause of injury			0.892	0.640
Car accident injury	18 (47.37)	21 (58.33)		
High falling injury	8 (21.05)	6 (16.67)		
Sports related injury	12 (31.58)	9 (25.00)		
Time for medical treatment (h)	1.56±0.48	1.44±0.41	1.153	0.253
Educational degree			0.467	0.509
Below junior high school	13 (34.21)	15 (41.67)		
Junior high school or above	25 (65.79)	21 (58.33)		
Place of residence			1.130	0.288
Urban	23 (60.53)	26 (72.22)		
Rural	15 (39.47)	10 (27.78)		

symptom disappearance, such as pain and swelling at the fracture site, well-recovered joint function, and normal joint structure on the MRI examination. Good was defined as significant improvement in symptoms and joint function, normal joint structure on the MRI examination, and a difference of less than 1 cm between the length of the affected limb and the healthy limb. Poor was defined as poor healing at the fracture site and a length difference of more than 1.5 cm between the affected limb and the healthy limb on the MRI examination. The percent of excellent and good outcomes was defined as (excellent + good)/total ×100%. Ankle function recovery and symptoms were scored with the Mazur Scoring System which is shown in **Table 1**. It is a new personal classification. The incidence of complications was compared between the two groups. Pain: visual analogue score (VAS) was used to score the patients before treatment (T0), 3 days after treatment (T1), and 7 days after treatment (T2). A lower score indicates a milder pain. The quality of life (QOL) score, covering physical functioning, social functioning, mental health, vitality, and bodily pain, was performed at 6 months after discharge. A higher score indicates a better prognosis.

Statistical methods

SPSS 24.0 (Yuchuang Network Technology Co., Ltd., Shanghai, China) was used in this study to analyze the results, and all graphical results were plotted using Graphpad 5. The counting data were expressed in the form of percentage (%), and the intergroup comparisons were performed by *Chi*-square test. The measurement data were expressed in the form of mean ± standard deviation (mean ± SD), and the intergroup comparisons were conducted by t-test. Multi-time point comparisons were performed by repeated measures ANOVA, and the post-hoc analysis was done by Bonferroni test. $P<0.05$ indicated that the difference was statistically significant.

Results

Comparison of general data

There was no significant difference in the clinical data between the two groups of patients in terms of age, gender, fracture site, cause of injury, time for medical treatment, educational level, and place of residence ($P>0.05$) (**Table 2**).

Comparison of general indices

The comparison of general indices showed that the operation time, fracture healing time, and ambulation time of the patients in the RG were significantly shorter than those in the CG ($P<0.05$) (**Table 3**).

Table 3. Comparison of general indices between the two groups

General indices	RG (n=38)	CG (n=36)	*t*	*P*
Operation time (min)	83.63±15.46	102.35±18.24	4.771	<0.01
Fracture healing time (weeks)	12.71±2.06	15.32±2.28	5.172	<0.01
Ambulation time (weeks)	10.87±2.55	12.15±2.63	2.126	0.037

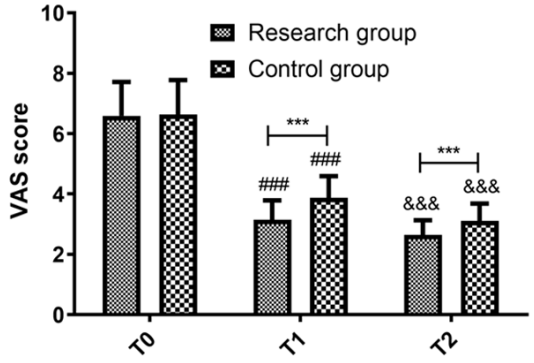

Figure 1. Comparison of VAS scores at different time points between the two groups. ###*P*<0.001, &&&*P*<0.001, compared with T0 within same group; ***P*<0.001, compared between two groups at the same time point.

Comparison of pain score (VAS)

There was no significant difference in the VAS score between the two groups at T0, but the VAS scores at T1 and T2 in the RG were significantly lower than those in the CG (*P*<0.001). The VAS score was the highest at T0, decreased at T1, and the lowest at T2 (*P*<0.001) (**Figure 1**).

Comparison of clinical efficacy

The comparison of treatment outcome revealed that the percentage of patients with excellent and good outcomes in the RG were higher than those in the CG (*P*<0.05) (**Table 4**). As shown in **Figure 2**, it was found that in the RG, the distal end of the left tibia was dislocated, and fractured pieces of bone were well aligned and stable following internal fixation, while in the CG, the fractured end was dislocated preoperatively, and the fracture line involved the articular surface and the alignment of the fractured end after operation was acceptable.

Comparison of Mazur scores

The pretreatment Mazur Score did not differ significantly between the two groups (*P*>0.05). At 6 months after treatment, the score rose remarkably in both groups (*P*<0.001), and the average score in the RG was significantly higher than that in the CG (*P*<0.05) (**Table 5**).

Comparison of incidence of complications

The complications were compared between the two groups, and the result showed that the incidence of complications in the RG (2.63%) was significantly lower than in the CG (19.44%) (*P*<0.05) (**Table 6**).

QOL score

The QOL of patients was scored at 6 months after discharge. The average score of the RG (76.17±8.57) was significantly higher than that of the CG (71.54±8.02), and the score of the RG in each dimension was better than that of the CG (*P*<0.05) (**Table 7**).

Discussion

The ankle joint is one of the typical hinged joints of human body. It can be affected by various conditions, such as trauma, overuse disorders, and inflammation, and injuries account for about 14% of sports-related orthopedic examinations [11, 12]. Among them, triplane fracture of the distal tibia, a rare injury of the ankle joint, it is a unique fracture in adolescence caused by daily sports [13]. It has been reported that about 4% of pediatric fractures occur in the ankle, of which only 6% are triplane fractures, accounting for about 10% to 15% of all intra-articular ankle fractures in children [14]. Triplane fracture of the distal tibia is a complex fracture type involving the epiphyseal plate and often requires surgical treatment. This may lead to malunion and cause complications, thus affecting growth, development, or the daily life of patients [15, 16]. Therefore, the most stable, comfortable, and effective treatment should be selected as far as possible. Through a series of analyses, this study compared the effect of traditional APs and full-threaded HCCSs in the treatment of triplane fractures of the distal tibia to provide guidance for future treatment of this fracture type.

Firstly, age, gender, fracture site, cause of injury, time of treatment, educational level, and

Table 4. Comparison of efficacy between the two groups [n (%)]

Efficacy	RG (n=38)	CG (n=36)	χ^2	*P*
Excellent	22 (57.89)	19 (52.78)		
Good	15 (39.47)	11 (30.56)		
Poor	1 (2.63)	6 (16.67)		
Excellent and good rate (%)	97.37%	83.33%	4.252	0.039

Figure 2. MRI image before and after treatment of the two groups. MRI images of pre-treatment (A) and post-treatment (B) in research group. MRI images of pre-treatment (C) and post-treatment (D) in control group.

Table 5. Mazur scores of patients in the two groups

Group	Before treatment	6 months after treatment
RG (n=38)	25.86±5.17	92.12±6.15*
CG (n=36)	25.23±4.96	88.54±5.62*
T	0.534	2.610
P	0.595	0.011

Note: *indicates *P*<0.001 compared with that before treatment.

Table 6. Comparison of complications between the two groups [n (%)]

Complications	RG (n=38)	CG (n=36)	χ^2	*P*
Infection	0 (0.00)	3 (8.33)		
Skin necrosis	0 (0.00)	1 (2.78)		
Looseness of internal fixation	1 (2.63)	1 (2.78)		
Rupture of internal fixation	0 (0.00)	2 (5.56)		
Incidence (%)	2.63%	19.44%	5.420	0.020

place of residence had no influence on postoperative fracture healing. The operation time, fracture healing time, and ambulation time in the RG that received full-threaded HCCSs were significantly shorter than those in the CG. We speculate that this is because the triplane fractures of the distal tibia are more complex, and traditional anatomical steel plates cannot completely match the bone surface of all patients, which increases the difficulty of operation, resulting in longer operation and postoperative recovery time, as well as more complications [6]. Furthermore, the proportion of patients with excellent and good outcomes and the Mazur Scores in the RG were notably higher than those in the CG, indicating that full-threaded HCCSs treatment was more beneficial to fracture healing and ankle function recovery. This may be because full-threaded HCCSs are more effective in fixing the fracture end and are more conducive to fracture surface healing [17]. Compared with full-threaded HCCSs, AP treatment caused more complications, such as infections and loosening or rupture of the internal fixation. Although traditional AP internal fixation reduces triplane fractures of the distal tibia in adolescents, it causes a larger wound surface and increases the risk of infection. In addition, the unpressurized fracture ends (where elastic compression of the fracture ends is not applied with an external fixator) are prone to fracture movement and separation. A study has found that full-threaded HCCSs are safe with a low incidence of complications that can be effectively managed [18], which are consistent with the above results. Therefore, full-threaded HCCSs

Table 7. QOL score of patients in the two groups

Item	RG (n=38)	CG (n=36)	*t*	*P*
Physical functioning	83.25±9.86	77.81±9.14	2.458	0.016
Social functioning	80.11±9.32	75.62±8.85	2.123	0.037
Mental health	73.07±8.41	68.97±8.16	2.127	0.037
Vitality	67.54±7.42	62.13±6.85	3.254	0.002
Bodily pain	76.88±7.84	73.19±7.1.2	2.116	0.038
Average score	76.17±8.57	71.54±8.02	2.396	0.019

are safer since they provide more robust fixation. Moreover, there was no significant difference in pain scores between the two groups before treatment, and the pain scores of patients in the RG were significantly lower than those in the CG after treatment. Another study has found that the use of headless compression screws is an appropriate choice in the ankle area owing to their advantages of providing successful fixation whilst not causing screw head irritation or pain due to being a less invasive approach, allowing shorter time to union, and lower complication rates [19].

Finally, a 6 month follow-up was conducted after surgery and found that the QOL scores in the RG were better than those in the CG, indicating that compared with traditional APs fixation, the use of full-threaded HCCSs was less painful, more conducive to recovery, and led to better long-term prognosis. A follow-up study also showed that no patient had loss of reduction, evidence of implant migration, or metallic failure, which is consistent with the above results [20].

The purpose of this study was to investigate the difference of therapeutic effects between full-threaded HCCSs and APs in the treatment of triplane fractures of the distal tibia, and to explore a more appropriate treatment method. However, there are limitations to the study. For example, at present, there are few reports on full-threaded HCCSs and APs and their treatment, so it is impossible to compare the findings of our study with other literature results. In addition, due to the small sample size, it is possible that other studies may not capture the full spectrum of related incidences. We will continue to improve the results in future studies.

In summary, compared with APs, full-threaded HCCSs are more effective and safer, and can improve patient prognosis while reducing the incidence of complications.

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Disclosure of conflict of interest

None.

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