Application of one-third tubular steel plates and screws for fixation of medial column in pilon fractures

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Background: The present study sought to explore the efficacy of one-third tubular steel plates and screws for the treatment of medial column of pilon fractures.

Methods: The present retrospective study comprised 40 subjects with Rüedi-Allgöwer type III pilon fractures that attended Northern Jiangsu People's Hospital from April 2016 to April 2019. Patients were assigned to 2 groups based on reconstruction and fixation components used on the medial column. The medial column of participants in the control group (n=20) was anchored using screws. The medial column for subjects in the treatment group (n=20) was reconstructed using a one-third tubular steel plate. The American Orthopaedic Foot and Ankle Society (AOFAS) ankle-hindfoot score at 1, 2, 3, 6, 12 and 24 months after operation, intraoperative blood loss, fracture healing time, preoperative detumescence duration, operation time, postoperative weightbearing duration, and postoperative Burwell-Charnley radiological score of the 2 groups were compared.

Results: The findings showed that intraoperative blood loss, preoperative detumescence time, and operation time for the treatment group were not statistically different relative to the control group (P>0.05). The fracture healing time and postoperative weightbearing time in the treatment group were 15.07±0.98 weeks and 6.91±0.61 weeks, respectively, while those in the control group were 15.84±0.59 weeks and 8.60±0.53 weeks, respectively (P<0.05). Patients in the treatment group showed markedly higher AOFAS scores relative to the AOFAS scores of subjects in the control group at month 1, 2, and 3 post-operation (P<0.05). AOFAS scores for the 2 groups were not significantly different at month 6, 12 and 24 post-operation. Subjects in the control group had a significantly lower Burwell-Charnley number radiology score relative to that of subjects in the treatment group (P<0.05).

Conclusions: The present findings show that the medial column of subjects with Rüedi-Allgöwer type III pilon fracture can be repaired using a one-third tubular steel plate. Compared with simple screw fixation, the use of a one-third tubular steel plate allows earlier postoperative weightbearing, decreases the rate of postoperative reduction loss, and leads to better clinical effects and prognosis.

Keywords: Pilon fracture; medial column; four-column theory; one-third tubular steel plate; internal fixation

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Introduction

Pilon fractures and long bone fractures are the most common types of tibial fractures, and account for 5% to 7% of all tibial fractures (1). The number of pilon fractures has recently increased owing to rising incidence of car accidents and high-energy trauma. Pilon fractures were first described by the French radiologist Destot, who reported that distal tibia was analogous to a medical pestle. Studies report that vertical striking and pressing of the talus against the distal tibia results in distal tibia fractures. This type of ankle fracture involves the tibiotalar articular surface and is often accompanied by distal cancellous bone compression, bone loss, and fibula fracture, intense reduction of surface of distal articular in tibia (2).

Pilon fractures are typically caused by resultant forces such as rotation, shear and axial compression. Nonunion of fractures, high rate of postoperative infection, significant destruction of the articular surface, and swelling of soft tissue all provide challenges for treatment and prognosis of pilon fractures. The choice of internal fixation material is critical for achieving early functional exercise and good anatomical reduction (3). At present, studies report contrasting findings on medial column fixation in the surgical treatment of pilon fractures. Informed by their own clinical experience, health practitioners use screws, traditional reconstruction plates or clover plates when reconstructing the medial column in order to reach the fracture site directly, minimize the surgical incision, and reduce the peeling of soft tissue and periosteum as much as possible. According to previous literature, the use of screws in medial column reconstruction reduces soft tissue irritation, which is already gradually thinned. In addition, it promotes postoperative bone tissue regeneration and results in less damage to blood supply in the distal tibia. However, the fixation strength of screws is not sufficient to allow early postoperative weightbearing. This increases the incidence of complications resulting from prolonged bed rest, such as joint stiffness, postoperative adhesion, and respiratory and urinary tract infections. In contrast, the strong fixation provided by clover plates and reconstruction plates reduces the incidence of postoperative blood loss and ensures early commencement of postoperative functional exercise. However, the thickness of these steel plates can irritate the thin soft tissue of the medial malleolus, leading to postoperative infection, fracture nonunion, and delayed union. In addition, the physiological radians of clover plates and reconstruction plates attach to the medial column, and the position of the nail hole is inflexible, which increases operative difficulty for patients with comminuted fractures and more fracture lines. Previous studies have not compared the clinical outcomes of using one-third tubular steel plates and screws to fix medial column of pilon fractures. Thus, a retrospective analysis of the clinical data of subjects diagnosed with pilon fractures who had undergone treatment using one-third tubular steel plates or screws in our hospital. The purpose was to improve therapeutic outcomes for patients by identifying a more effective means of fixation. We present the following article in accordance with the STROBE reporting checklist (available at https://atm.amegroups.com/article/view/10.21037/atm-22-92/rc).

Methods

Enrollment of study participants

The inclusion criteria of the present study were: (I) patients older than 18 years old with epiphyseal closure and a fracture occurring no more than 3 weeks; (II) patients who had undergone X-ray or CT examination for diagnosis of Rüedi-Allgöwer type III pilon fracture; (III) patients not diagnosed with intense fractures, such as talus and calcaneal fractures; (IV) subjects who had good ankle joint function before the injury; (V) patients without congenital malformation of the ankle joint; (VI) a follow-up period of at least half a year or more.

The exclusion criteria of the study were: (I) subjects aged below 18 years; (II) patients with multiple severe fractures of the whole body, including calcaneal fractures or talus fractures; (III) patients with pathological fractures; (IV) patients with irreversible vascular and nerve injury of the ankle joint; (V) patients whose basic condition was not good enough to tolerate the operation.

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Ethics Committee of Northern Jiangsu People's Hospital, China (No. 2021ky295). All patients gave informed consent before participation.

General information

A total of 40 participants with Rüedi-Allgöwer type III pilon fracture who were treated at Northern Jiangsu People's Hospital from April 2016 to April 2019 were enrolled in the current study. Participants were assigned to treatment group and control based on the type of fixation strategy used. Screws were selected as the fixation method in the control group and one-third tubular steel plates were selected as the fixation method for the treatment group. The control group comprised 7 females and 13 males, with an average age of 48.7 years (ranging between 34–66 years), whereas the treatment group comprised 12 male subjects and 8 female participants. The average age of the subjects in the treatment group was 55.2 years (age range, 41–71 years). The subjects underwent debridement within 8 hours after admission. In addition, the subjects in the present study underwent calcaneal traction conducted in the hospital emergency room. Local swelling was reduced to ensure only few skin folds were visible, and alleviation of tension blisters by raising and immobilizing the affected limb. Patients were treated with internal fixation, based on the blood biochemical indicators (4).

Surgical method

The patient underwent intraspinal anesthesia and was placed in the floating position, with an air bag tourniquet tied to the affected thigh to maintain the pressure at 450 mmHg. The region of the limb between the tourniquet and toes was sterilized. The outer edge of the fibula and Achilles tendon was incised using posterolateral approach, carefully to avoid injury of the small saphenous vein and sural nerve in the process of incision. Subsequently, the fibula was fully exposed by pulling the lateral long-short fibula tendon and the medial long flexor tendon, and the fracture rotation deformity was corrected by reduction of the fibula. After satisfactory reduction, a lateral malleolus plate was used for fixation. Then the fragments of the posterior column fracture were exposed bluntly along the posterior edge of the long-short fibula muscle in the same incision. The posterior Volkmann fracture fragment was applied for indirect decrease of the articular surface to indicate a decrease in the tibia posterior marginal bone cortex. Anatomical reduction of the posterior column was performed through multidirectional and repeated use of a C-am machine. A T-shaped steel plate was used to fix the posterior column. Subjects were placed in a supine position while maintaining ankle toe flexion. The region between tibial crest and the tibialis anterior muscle was used for anterior median incision. The incision was slightly inclined at the edge of medial malleolus after reaching the joint. The medial malleolus fracture line was incised horizontally to determine the incision length. The distance between the incisions was above 7 cm. Sequential incision of skin and the subcutaneous soft tissue was performed, taking care to avoid injury of saphenous nerve as well as the great saphenous vein. The medial and anterior sides of the distal tibia were fully exposed. First, the impacted "die-punch" bone blocks were cleaned, and then the articular surface as well as the soft tissue embedded to it were cleaned to minimize congestion. The level of the ankle articular surface was accurately determined using Tillaux-Chaput nodule for realigning of the ankle articular surface and to improve smoothness of distal tibia articular surface. The bone defect was treated with an autogenous bone graft or an artificial bone graft. After the satisfactory alignment of the fracture was confirmed by repeated fluoroscopy, the fracture was fixed with an anterolateral L-shaped locking plate. Finally, the medial malleolus was reduced by performing a similar incision. A Kirschner wire was used to temporally fix the medial column of subjects in the treatment group then firmly fixed with a one-third tubular steel plate after anatomical reduction of the fluoroscopic fracture (*Figure 1*). Screws were used to fix the medial column of subjects in the control group (*Figure 2*). Screws were positioned perpendicularly to the fracture line and arranged in a scattered formation, taking care not to insert the screws into the ankle joint. To reduce complications and soft tissue destruction, operation is performed as gently as possible. The high volume of normal saline was used to repeatedly was the surgery region after the operation. An aseptic gauze was used for bandaging of the incision after double-layer closing.

Postoperative management

Subjects recruited to the study were frequently treated using analgesia, anti-infective drugs for 48 hours, and dressing changes. Deep venous thrombosis was presented by intramuscular injection of all patients with 4,000 U low-molecular-weight heparin on hour 24 after the operation. The subjects in the study underwent extension and flexion exercises for toes, ankles, and knees on day 2 under the guidance of the rehabilitation department. Further X-rays examinations were conducted and postoperative fracture reduction was evaluated by determining the Burwell-Charnley radiology score. Stitches were removed 2 weeks after the operation according to the condition of the incision. A reexamination was performed at 4 weeks after operation, including imaging examination and American Orthopaedic Foot and Ankle Society (AOFAS) score. Partial weightbearing on crutches was carried out between 6 to 8 weeks after the operation. The patients were reexamined at 1, 2, 3, 6, 12, 24 month (*Figure 3*).

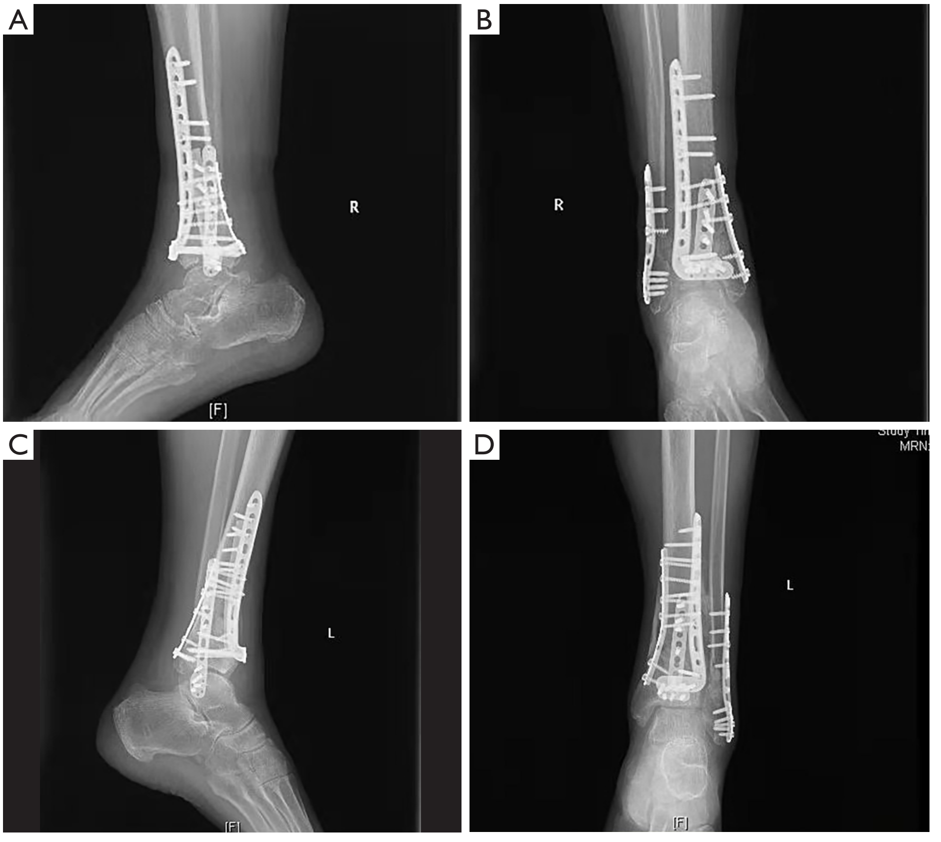

Figure 1 Postoperative X-ray in the treatment group. The medial column fracture of the ankle was fixed by a one-third tubular plate. The one-third tubular steel plate firmly fixes the fracture without prebending of the steel plate while ensuring strong fixation and provides good supporting and anti-skid functions.

Statistical analyses

SPSS 23.0 (IBM Corp., Armonk, NY, USA) was utilized for data analysis. The ankle-hindfoot function score determined using AOFAS scale at month 1, 2, 3, 6, 12, 24 after the operation, intraoperative blood loss, age, postoperative weightbearing time, fracture healing time, preoperative detumescence time, and operation time were tested by a *t*-test of 2 independent samples (5). The postoperative Burwell-Charnley radiological scores of the 2 groups were compared by a chi-squared test (6), and a $P<0.05$ showed statistical significance.

Results

General data

The internal fixation operations were successfully completed in both groups, and the incisions of all patients healed well with no postoperative neurological complications. The results showed that age and preoperative detumescence time of patients in the treatment group did not show significant differences relative to that of subjects in the control group ($P>0.05$).

Comparison of treatment processes

The findings showed that age, sex, operation time, or intraoperative blood loss of the 2 groups showed without statistical differences ($P>0.05$). The fracture healing duration of subjects in the treatment group (15.07±0.98 weeks) was markedly lower relative to the fracture healing time of subjects in the control group (15.84±0.59 weeks; $P<0.05$). The postoperative weightbearing duration of subjects in the treatment group (6.91±0.61 weeks) was markedly less relative to the postoperative weightbearing time of the control group (8.60±0.53 weeks; $P<0.05$; *Table 1*).

Figure 2 Postoperative X-ray in the control group. In the early stage of fracture reduction, the transtubular lag screw achieved strong fixation. However, reduction loss gradually increased with the recovery of ankle function.

Figure 3 Display of flexion and extension of an ankle joint in the treatment group 2 months after the operation. The patient's ankle had regained its range of motion and begun to carry weight gradually.

Postoperative AOFAS score results

The post-operative AOFAS scores of the subjects in the treatment group were markedly higher relative to the post-operative AOFAS scores of the control group at month 1, 2, and 3 (P<0.05; *Table 2*). The AOFAS scores of the 2 groups did not show significant differences at month 6, 13 and 24 (*Figure 4*).

Table 1 Baseline patient characteristics of the two groups

Characteristics	Treatment group	Control group	t/χ^2	P
Age, year	55.20±10.10	48.7±10.30	1.39	0.18
Sex, Male/Female, number	12/8	13/7	2.40	0.12
Preoperative detumescence time (day)	10.20±4.05	10.50±3.69	−0.17	0.86
Operation time (hour)	2.83±0.47	2.17±0.45	1.96	0.07
Intraoperative blood loss (mL)	120±48.30	131±84.00	−0.36	0.72
Fracture healing duration (week)	15.07±0.98	15.84±0.59	−2.13	0.05
Postoperative weightbearing time (week)	6.91±0.61	8.60±0.53	−6.63	0.01

Table 2 Postoperative ankle function was evaluated by AOFAS score

Groups	AOFAS score#					
	1 month	2 months	3 months	6 months	1 year	2 years
Treatment group (N=20)	65.50±2.01	75.80±2.04	86.00±2.26	86.20±1.69	86.30±1.70	86.9±2.60
Control group (N=20)	56.40±3.53	66.30±2.95	73.90±3.11	85.00±0.94	85.30±0.95	84.8±1.87
t/χ^2	7.08	8.38	9.96	1.96	1.62	2.07
P	0.00	0.00	0.00	0.07	0.25	0.23

#, time after surgery. AOFAS, American Orthopaedic Foot and Ankle Society.

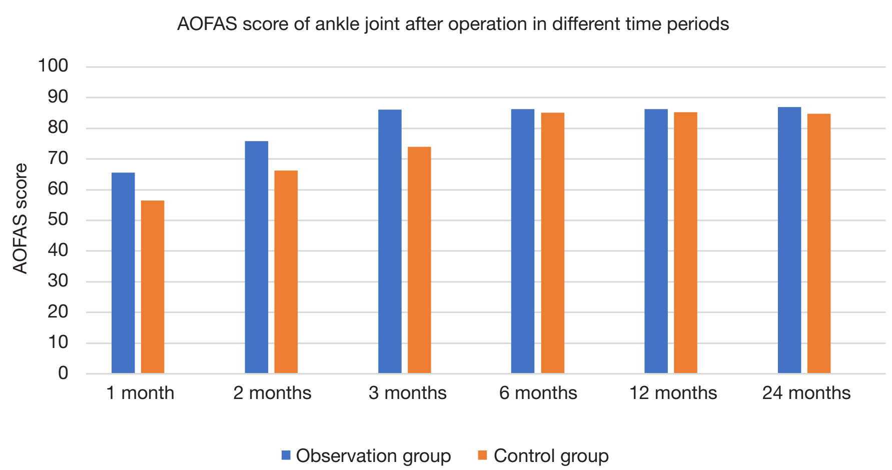

Figure 4 AOFAS scores of participants in the treatment group and control group. AOFAS, American Orthopaedic Foot and Ankle Society.

Postoperative Burwell-Charnley radiology score of the two groups

The day after the operation, in the treatment group, the Anatomical Reduction, Acceptable Reduction, Poor Reduction number were 16, 2, 2. The Anatomical Reduction rate was 80%. In the control group, the values were 15, 3, 2, respectively. The reduction rate was 75%. The Burwell-Charnley radiology scores were statistically different for the treatment and control groups (P>0.05). The number of observations on month 6 was 16, 2, 2 with 80% reduction rate. As for the control group, the number was 10,6,4. The rate was 50%. The Burwell-Charnley number radiology score of subjects in the control group was

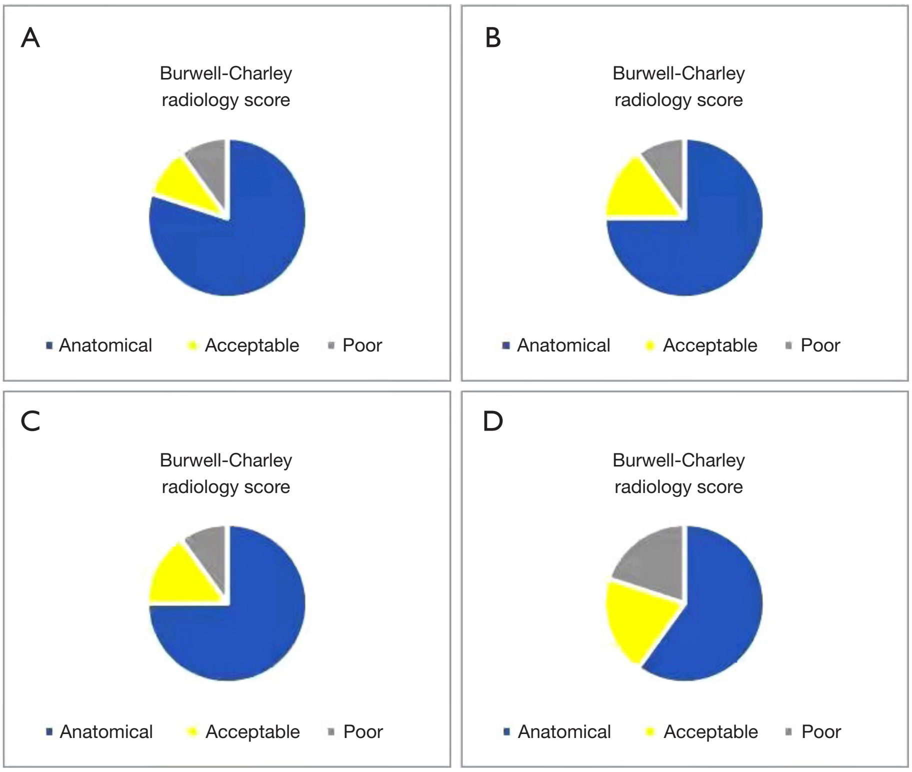

Figure 5 The day after the operation. (A) Postoperative Burwell-Charnley radiology scores of subjects in the treatment group after the operation. (B) Postoperative Burwell-Charnley radiology scores of participants in the control group after the operation. (C) Postoperative Burwell-Charnley radiology scores of subjects in the treatment group at month 6 after surgery. (D) Postoperative Burwell-Charnley radiology scores of subjects in the control group at month 6 after the operation.

markedly less relative to the score of the treatment group (P<0.05) (*Figure 5*).

Discussion

Since their first description in 1911, pilon fractures have been classified in different ways, such as the V-type longitudinal compression fracture described by Lauge-Hansen in 1963. In the present day, AO/OTA classification and Rüedi-Allgöwer classification are commonly applied in the clinic and are effective in classifying the degree of joint comminution and displacement. However, these classification systems are both based on X-ray. With the improvement of technology, Klammer *et al.* (7) recommended that CT three-dimensional reconstruction should be applied for treatment, diagnosis and assessment of pilon fractures after operation. Moreover, Tang *et al.* (8) reported that fracture classification should be performed using a four-column theory centered on CT three-dimensional reconstruction. The four-column classification comprises the division of the tibia into 4 columns. A line joining medial malleolus and lateral malleolus vertices is used to divide the anterior and posterior columns, while central axis of tibia and fibula distal articular surface surgical planes are used to divide the medial and lateral columns. The four-column classification was proposed to guide the selection of the surgical approach and internal fixation process. Chen *et al.* (1) Demonstrated the staged surgical protocol combined with the four-column classification was a viable approach to protect soft tissue and reduce fractures.

Rüedi *et al.* proposed medial column fixation as one of the four principles of pilon fracture treatment (9). However, there is still no consensus on the method applied for medial column fixation and improper treatment and unstable fixation often lead to adverse consequences such as joint dysfunction, traumatic arthritis, skin necrosis, and internal fixation failure. A cross section analysis shows that the distal end of the tibia from the top to bottom changes from a triangular shape to a quadrilateral shape, with reduction in the amount of soft tissue covering the tibia. Intramedullary vessels supply two-thirds of the blood in tibia, whereas the soft tissue attached to the surface supplies a third of the blood. Intramedullary blood vessels are injured by pilon fractures. Fixing of plates and open reduction aggravate the soft tissue injury, ultimately reducing supply of blood to the distal tibia and resulting in skin infection, fracture nonunion, and post-traumatic arthritis. Kottmeier *et al.* (10) found that the risk of nonunion after surgery of the distal tibia was more than that of other fractures. Blauth *et al.* (11) proposed treatment of pilon fractures using the 3P (Preserve, Perform, Provide) concept. The initial action (Preserve) is to restore supply of blood to the soft tissue and bone. Taking into account high skin tension and lack of soft tissue in medial malleolus, Falzarano *et al.* (12) conducted internal fixation using materials that reduced peeling of the soft tissue, such as Kirschner wire, tension screws, hollow screws, and so on. This reduces the risk of skin necrosis, fracture nonunion, and other complications resulting from soft tissue irritation brought about by too many implants and reduces cost of materials, surgical incision, blood loss, and the operation time compared with steel plate reconstruction of the medial column (13). However, during actual operations, Tong *et al.* (14) found that the proximal end of the tension screws, hollow screws and Kirschner wire were loosened due to the comminution of the bottom of the tibia. In addition, the author found fretting of the medial bone during flexion and extension of an ankle joint fixed with screws. Screw fixation decreases the risk of bone exposure, postoperative skin necrosis, fracture nonunion, and delayed union. However, it increases the risk of pulmonary infection, pressure sores, ankle stiffness, and ankle dysfunction as a result of the delayed starting time of postoperative functional exercise. Premature weightbearing may lead to adverse events including fracture of internal fixation, loss of postoperative reduction, and refracture (15). Simple metal screws or Kirschner wire are affected by shear force during functional exercise owing to the loadbearing function and the unique physiological structure of the ankle joint (16).

Strong and thin fixation materials with less irritation to the medial column soft tissue are used to minimize adverse events. Gao *et al.* (17) fixed the medial column using a multiaxial locking plate. The results indicated that the risk of soft tissue infection was reduced, although the plate was thicker than the screws. Feng *et al.* (18) and Amorosa *et al.* (19) reconstructed the medial column with a tubular plate and a locking plate, separately and observed some good therapeutic effects. Through biomechanical experiments, Wegner *et al.* (20) confirmed that the fixation stiffness of anti-slide plates was 4 times that of monocortical screws when used to fix oblique fractures of the medial column in pilon fractures. In the current study, X-ray results and the ankle function postoperative AOFAS scores of patients in the treatment group (one-third tubular steel plate) and the control group (screws) at 3+ months after the operation were compared. Our results showed that some participants in the control group lost the medial column reduction after the operation due to early weightbearing and functional exercise (*Figure 2*), while effective medial column fixation in the treatment group ensured the safety of early weightbearing activities. Similarly, Miller *et al.* (21) found that when there is firm internal fixation, early partial weightbearing on the fracture provides appropriate stress stimulation and has a better curative effect than that seen in patients who underwent delayed postoperative exercise (*Figure 3*). In our study, subjects in the treatment group exhibited markedly higher AOFAS ankle function scores relative to scores of subjects in the control group in month 1, 2 and 3 post-operation, which further indicates that one-third tubular steel plates are more stable than screws for medial column reconstruction. The findings showed that subjects in the treatment group did not present with side effects including bone nonunion, infection and soft tissue irritation during the postoperative follow-up. Li *et al.* (22) analyzed fracture mechanisms from the perspective of Tang Xin's four-column theory. They suggested that the axial impact force results in moving of the talus forward laterally in the ankle joint, resulting in involvement of the central anterolateral region of the distal tibial articular surface. The ankle joint develops a varus tilt when the injury force increases, resulting in more severe medial column injury compared with the lateral column injury. Haller *et al.* (23) reported that effective fixation of medial column decreases nonunion incidence for patients with pilon fractures. The medial column and the other 3 pillars support each other to form a stronger ankle joint, so stable fixation of the medial column is critical to ensuring that the patient can begin timely functional exercise, which promotes fracture healing. Therefore, a one-third tubular steel plate is the preferred material for medial column fixation of pilon fractures.

Our study has some limitations. The present study did not evaluate internal fixation such as reconstruction plates and locking plates. Moreover, the study used a small sample size, thus necessitating a multicenter, large sample prospective clinical study. It is worth mentioning that the cost of one-third tubular steel plates is higher relative to that of screws, which limits their clinical application.

Conclusions

After comprehensive consideration, we believe that one-third tubular plates provide stronger fixation and allows earlier postoperative weightbearing when used for medial column reconstruction in pilon fractures.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://atm.amegroups.com/article/view/10.21037/atm-22-92/rc

Data Sharing Statement: Available at https://atm.amegroups.com/article/view/10.21037/atm-22-92/dss

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://atm.amegroups.com/article/view/10.21037/atm-22-92/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Ethics Committee of Northern Jiangsu People's Hospital, China (No. 2021ky295). All patients gave informed consent before participation.

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