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Treatment of AO/OTA type 43-C3 pilon fractures with a combination of miniplate and main plate: a retrospective analysis

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Abstract

Background AO/OTA type 43-C3 pilon fractures are complex distal tibial fractures associated with high disability rates, surgical challenges, and frequent postoperative complications. Effective treatment of type-C3 pilon fracture remains an important research focus. This study aimed to evaluate the efficacy of a combined miniplate and main plate fixation strategy compared to traditional treatment methods.

Methods A retrospective analysis was conducted on 64 patients with type 43-C3 pilon fractures treated between June 2018 and June 2022. Patients were divided into a miniplate group (MP group, $n = 31$) and a traditional treatment group (TT group, $n = 33$). Outcomes including operative duration, reduction quality, fracture healing, complications, functional scores (AOFAS, VAS, ROM), and hospitalization data were analyzed.

Results The surgery was completed successfully in both groups, and the average follow-up duration was 16.78 ± 3.27 months. There were no significant differences in the duration of preoperative waiting, hospital stay, and weight-bearing between the two groups ($P > 0.05$). The duration of surgery was significantly shorter in the MP group than in the TT group ($P < 0.05$). The quality of fracture reduction and healing at 6 weeks after surgery in the MP group was significantly better than that in the TT group ($P < 0.05$). There was no significant difference in the visual analog scale scores between the two groups. However, at 6 months postoperatively and at the last follow-up, the American Orthopedic Foot and Ankle Society score and ankle fire activity range of motion were significantly better for those in the TT group. There were two cases of ischemic osteonecrosis, two of poor incision healing, and one of severely poor wound healing in the TT group; however, only one patient in the MP group had poor incision healing.

Conclusion The use of miniplates combined with main plates in the treatment of type-C3 pilon fracture has obvious advantages, which simplifies the difficulty of the surgery, reduces the volume of the ankle joint, reduces postoperative complications, and is beneficial to postoperative exercise and ankle function recovery.

Keywords Pilon fracture, Mini plate, Internal fixation, AO/OTA type C, Treatment protocol

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Background

Pilon fractures are intra-articular fractures involving the weight-bearing joint surface of the distal tibia, which are high-energy injuries accounting for approximately 1% of lower extremity fractures and 10% of tibial fractures [1]. Clinically, the most reliable classification method for pilon fractures is the Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association (AO/OTA) classification [2]. Among these, C3 pilon fractures have a high disability rate, with severe soft tissue damage around the ankle, serious destruction of the articular surface, and comminution of the metaphyseal end. Because of metaphyseal and articular surface comminution, it is difficult to restore the articular surface flatness and force line. Previous studies have reported that the excellent reduction rate of C3 pilon fractures is 82% [3], incidence of bone non-union is 18% [4], and incidence of postoperative soft tissue infection and other complications is 10–35% [5]. Therefore, the treatment of C3 pilon fractures remains difficult in foot and ankle surgery.

Currently, there is some confusion in the literature regarding the best treatment strategy for C3 pilon fractures. General treatment principles include anatomical reduction of the fibula, reconstruction of the distal tibial articular surface, adequate bone grafting, and rigid internal fixation [6]. Open reduction and internal fixation remain the most commonly used surgical method for C3 pilon fractures. Since C3 pilon fractures are a special comminuted fracture, multiple implants are often required to stabilize the fracture mass in order to provide stable stress support to the metaphyseal of the tibia and maintain the articular surface flat, which undoubtedly increases the detachment of soft tissue. High-density plate screws can provide a strong fixation, but it increases the implant volume of the ankle joint and easily creates a rigid environment, which is not conducive to the postoperative rehabilitation of patients. In addition, it can easily cause non-union of the fractured end of the bone. The miniature plate has limited effect on the blood circulation of the periosteum and bone cortex and has a strong holding force [7]. A nail plate system is used to firmly fix the small bone mass and increase the contact area of the main plate, which is convenient for intraoperative reduction and to maintain the reduction effect. In view of this, we considered the surgical idea of a miniplate combined with a main plate in the treatment of type-C3 pilon fractures, using miniplates to reduce the large free bone mass first and to change the complex type-C3 pilon fracture into a type-B or even type-A fracture to simplify the difficulty of surgery, and finally insert the main plate to reconstruct the stability of the fracture.

In complex type-C3 pilon fractures, restoring the flatness of the articular surface and maintaining the vertical line of the lower extremities are the core steps in surgical treatment [8, 9]. This study introduced a surgical method and technique for treating type-C3 pilon fracture. The aim was to evaluate the feasibility and clinical practical value of a miniplate combined with the main plate in the treatment of type-C3 pilon fractures, to analyze the advantages and disadvantages of this surgical concept, and to compare it with the traditional treatment by comparing the results of the imaging and clinical efficacy.

Methods

Patients

The data from 64 patients with type-C3 pilon fractures who met the exclusion criteria and inclusion criteria between June 2018 and June 2022 were retrospectively analyzed. All patients were randomly divided into two groups. All patients knew and agreed to the operation plan, and were divided into MP group and TT group according to whether whether a miniplate was used during the surgery. There were 31 patients in the miniplate group (miniplate, MP) and 33 patients in the traditional treatment group (traditional treatment, TT). Of these, there were nine cases of traffic accident injury, 19 cases of high-fall injury, and three cases of smashing injury in the MP group, and nine cases of traffic accident injury, 20 cases of high-fall injury, and four cases of smashing injury in the TT group. The average age of the patients in the MP group was 40.26 ± 2.49 years and of those in the TT group was 39.58 ± 2.60 years. All patients were of the type-C3 according to the AO/OTA classification.

This study was approved by the hospital ethics committee, and all patients provided informed consent. The inclusion criteria were as follows: type-C3 pilon fracture based on AO/OTA classification; age > 18 years and < 60 years; follow-up duration > 1 year and complete clinical data; and open reduction and internal fixation. The exclusion criteria were as follows: old fracture; open fracture; and malfunction of ankle joint before injury, such as traumatic arthritis, congenital ankle deformity, and Kaschin-Beck disease.

Surgical procedure

Preoperative management

After admission, all patients underwent calcaneal tubercle traction, improved ankle joint position and lateral radiography, computed tomography (CT) in the coronal and sagittal planes to determine the fracture of the affected limb (Fig. 1). The affected limb was raised and local ice compression, mannitol, and other detumescence treatments were applied, following which the soft tissue swelling subsided, and skin wrinkles were observed after open reduction and internal fixation.

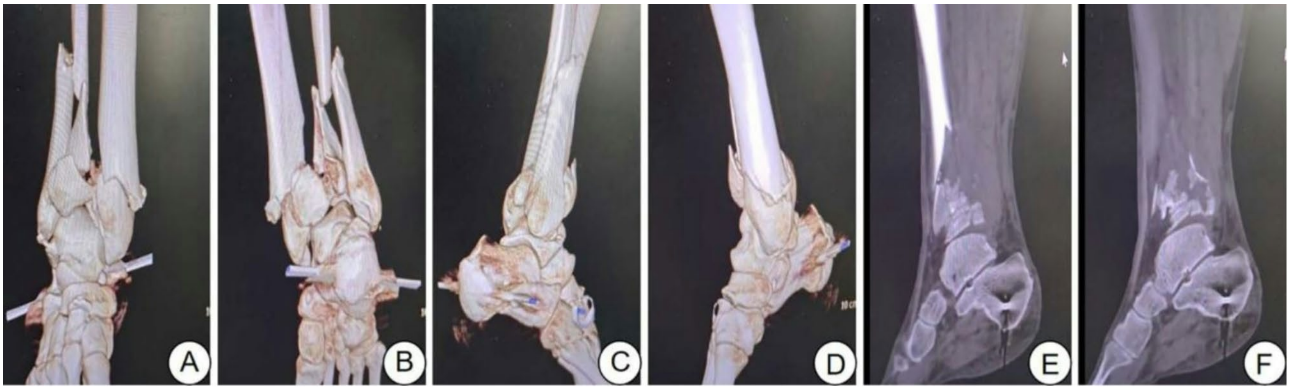

Fig. 1 Preoperative imaging data of a patient with type-C3 pilon fracture. **A**–**D**. Three-dimensional reconstruction of images of the fracture at different angles. **E**–**F**. Computed tomography images show fractures in both metaphysis and articular surface

Surgical technique

All procedures are performed by the same team of experienced foot and ankle surgeons. The limb was slightly internally rotated followed by a small medial incision, approximately 15-cm long, along the fibula crest. On slight medial deviation at the ankle level, the fractured end of the fibula was exposed, which was then cleaned, reduced under direct vision, affixed with a 3-tube steel plate, and the fibula fracture was fixed with screws. The extensor support band was opened and the muscles of the anterior group of the leg were pulled inward to expose the fractured end of the distal tibia and clean the blood clots. There was no significant difference in the treatment of medial and posterior malleolar fractures between the two groups. A small external rotation of the affected limb; posterior medial incision of the skin; incision of the skin, subcutaneous, and fascial periosteum; exposure of the medial and posterior ends of the tibia; cleaning of the incarcerated periosteum and tissue at the fracture end; traction reduction; and fixation of the posterior and medial fracture segment of the lower end of the tibia with two steel plates were used to maintain the position of the force line and ankle joint. After the medial and posterior malleoli were treated through the anterolateral incision, the fracture of the distal tibia was crushed. In the MP group, large bone fragments were fixed with a 2.7-mm miniplate. Finally, bone fragments of the distal tibial joint were prepared and reduced, and the fracture was temporarily fixed with a 1.2-mm Kirschner wire. After a good ankle reduction, L-type steel plates were placed on the anterolateral side. In the TT group, the larger bone mass was temporarily fixed with a Kirschner wire or plate and the main plate was placed anterolaterally after good ankle joint reduction. After the surgery, the operative field was irrigated, the negative-pressure drainage device was retained, and the incision was sutured layerwise and bandaged with gauze and cotton pad.

Postoperative care and rehabilitation

After the surgery, the gauze covered with an elastic bandage was slightly pressurized, the affected limb was adequately raised, and routine treatment was administered, such as detumescence, analgesia, anti-inflammatory agents, and prevention of blood thrombus. The wound dressing was changed 24 h after the surgery, and the active flexion and extension of the toe and ankle joints began to be exercised 2 days after the surgery with a gradual increase in the exercise intensity. One month after the surgery, according to the results of the radiographic re-examination, the affected limbs were subjected to weight-bearing exercises until normal walking was achieved.

Observation assessment

Perioperative data, including the duration of waiting before surgery, surgery, hospital stay, and weight-bearing, were recorded. Postoperative complications, such as incision infection, incision non-union, deep venous thrombosis, and fracture non-union, were closely observed. According to the Burwell–Charenley radioactive reduction standard [10], the reduction was divided into anatomical, fair, and poor reductions. Six weeks after the surgery, the fracture healing was evaluated using the modified Radiographic Union Scale for Tibial fractures (mRUST) [7](1 = no callus, 2 = callus formation, 3 = bridging callus, and 4 = remodeling). The sum of callus formations in the four cortices was calculated. mRUST score with a cut-off value of ≥ 11 was considered as high callus and < 11 as low callus. During the follow-up period, the functional activity range of motion (ROM) of the affected limb was recorded, and the clinical effect was evaluated according to the visual analog scale (VAS) and American ankle-hindfoot score (American Orthopedic Foot and Ankle Society [AOFAS]). For clinically significant monitoring indicators, the effect size for transparency was further reported and the minimum clinical important difference (MCID) was analyzed. To our knowledge, there are no established data on the MCID in the above

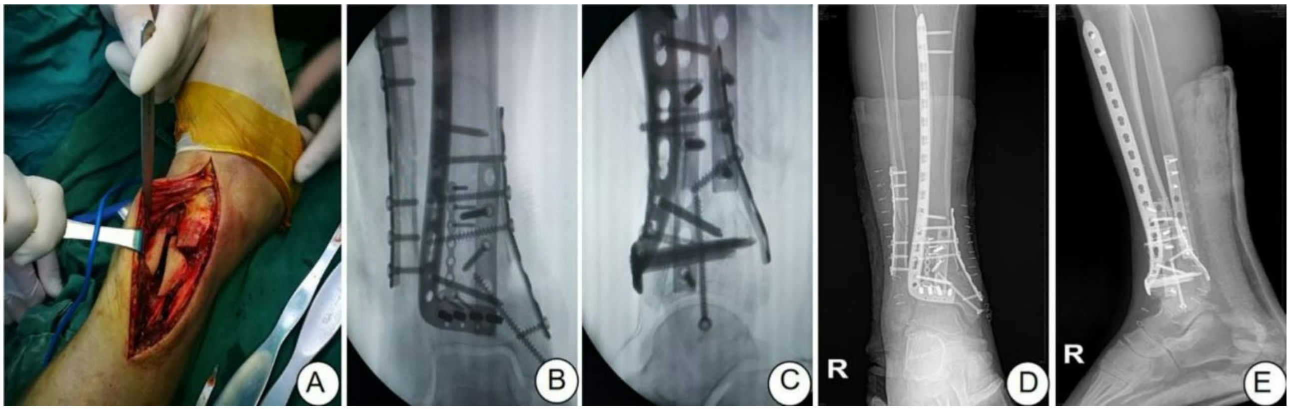

Fig. 2 Data of affected limbs during surgery. **A**. Multiple bone fragments can be seen after full exposure during the surgery. **B**–**C**. After the implantation of steel plate, the fracture has good reduction and internal fixation. **D**–**E**. Postoperative radiography showed that the reduction in the fracture was good with no obvious displacement compared with intraoperative fluoroscopy

Fig. 3 The related data of the patients during the last follow-up. **A**. At the last follow-up, radiography showed that the fracture had healed well and the internal fixation was in place with no obvious manifestations of traumatic arthritis. **B**. Coronal view of the fracture on computed tomography. **C**. Sagittal view of the fracture on computed tomography. **D**. Functional photographs of the affected limb and ankle joint at the last follow-up

outcome measures in a polulation with Pilon fracture. In these scenarios, an accepted method for estimating MCID is to use one-half the SD of the patient scores when they are maximally affected by the disease [11, 12]. If the difference at the lower limit of the 95% confidence interval (CI) for the monitoring measure is greater than the MCID, we consider the difference to be clinically significant.

Statistical analysis

Statistical analyses were performed using SPSS 26.0. The measurement data are expressed as $\overline{x}$±s. When the data were normally distributed, the independent sample t-test was used for comparison between the two groups, and the rank-sum test was used when the data were not normally distributed. Counting data were analyzed by the x^2 test or Fisher's exact test. The difference was considered statistically significant if $P<0.05$.

Table 1 Comparison of general characteristics between the two groups of patients

Patients	TT group (*n* = 33)	MP group (*n* = 31)	t/X^2 value	*P* value
Age (years)	39.58 ± 2.60	40.26 ± 2.49	-1.073	0.288
Sex (n, F/M)	20/13	18/13	0.043	0.836
Side (n, L/R)	17/16	16/15	0.000	0.994
BMI (kg/m^2)	24.58 ± 2.53	24.81 ± 2.75	-0.349	0.728
Smoking (n)	23/10	20/11	0.195	0.659
Open/Close (n)	8/25	6/25	0.223	0.636
Causes of injury (n)			0.106	0.948
Fall from height	20	19		
Car accident	9	9		
Hit by heavy object	4	3		

BMI, body mass index; F, female; M, male; L, left; R, right; MP, miniplate; TT, traditional treatment

Results

In this study, 64 patients were included and both groups underwent surgery successfully. The postoperative data are shown in Figs. 2 and 3. Other general data are presented in Table 1. The perioperative data are shown in Table 2.

Table 2 Comparison of perioperative data between the two groups

Patients	TT group (*n* = 33)	MP group (*n* = 31)	t/x^2 value	*P* value
Waiting duration before surgery (d)	6.27 ± 1.64	6.29 ± 1.55	-0.044	0.965
Duration of surgery (min)	138.48 ± 7.91	125.10 ± 5.33	7.98	**0.012**
Hospitalization duration (d)	15.39 ± 2.30	14.94 ± 2.64	0.741	0.462
Weight-bearing duration (w)	10.48 ± 2.68	10.81 ± 2.66	-0.481	0.632
Hospitalization expenses	4.39 ± 0.59	4.54 ± 0.61	-0.984	0.329
Burwell-Charenley (n)				
Anatomical reduction	8	21	-14.52	**< 0.001**
Reset can be	21	9		
Reset error	4	1		
mRUST 6 weeks after surgery				
≥ 11	10	20	-4.16	0.023
<11	23	11		

The bold words in the chart indicate statistical significance

MP, miniplate; TT, traditional treatment; mRUST, modified Radiographic Union Scale for tibial fractures

There was no significant difference in waiting duration before surgery and hospitalization duration between the two groups ($P > 0.05$). The operation time of the MP group was significantly less than that of the TT group, and the difference was statistically significant ($P<0.05$). There was no significant difference in the duration to start weight bearing or the duration to complete weight bearing between the two groups ($P > 0.05$). All patients were followed up for > 1 year, with an average follow-up duration of 16.32 ± 3.07 months. Six months after surgery, the AOFAS score (68.35 ± 6.36 [95%CI 66.02, 70.69]) and ankle ROM (16.16 ± 3.01 [95%CI 15.06, 17.27]) in the MP group were significantly higher than those in the TT group (60.97 ± 5.75 [95%CI 58.93, 63.01]) (11.82 ± 2.93 [95%CI 10.78, 12.86]), In addition, the difference between the lowest 95% confidence interval of AOFAS scores (7.09) is greater than MCID-AOFAS (3); the difference between the lowest 95% confidence interval of ROM (4.28) is greater than MCID-AOFAS (2), this means that the differences in AOFAS scores and ROM between the two groups are clinically significant. However the VAS score in the MP group was slightly lower than that in the TT group. At the last follow-up, the AOFAS score(88.68 ± 4.93 [95%CI 86.87, 90.49]) and ankle ROM (35.06 ± 3.76 [95%CI 33.69, 36.44]) in the MP group were significantly higher than those in the TT group(82.48 ± 8.74 [95%CI 79.39, 85.58]) (29.52 ± 4.34 [95%CI 27.98, 31.05]), the difference between the lowest 95% confidence interval of AOFAS scores (7.48) is greater than MCID-AOFAS (5); the difference between the lowest 95% confidence interval of ROM (5.71) is greater than MCID-AOFAS (3), this means that the differences in AOFAS scores and ROM between the two groups at the last follow-up are clinically significant. However, the VAS score in the TT group was slightly lower than that in the MP group. The follow-up data for the two groups are shown in Table 3.

All imaging data were observed and measured by three uninformed professionals. According to the postoperative imaging data, there were 21, 9, and one case in the MP group and 8, 21, and 4 cases in the TT group of anatomic, fair, and poor reductions, respectively. Six months postoperatively, there were 20 cases of high calluses in the MP group and 10 in the TT group. Complications were reported in one case in the MP group and two cases in the TT group. When complications of poor wound healing occurred, wound secretion culture was retained and drug sensitivity tests were performed. Patients with positive results were treated with sensitive antibiotics, and patients with negative results were treated with intravenous cephalosporin antibiotics to prevent wound infection. In addition, wound-dressing was changed daily and local physical therapy was used to keep the wound dry until wound healing. However, in the TT group, there was poor healing of the incision. After supportive and symptomatic treatment, the wound did not heal. Finally,

Table 3 Comparison of follow-up data between the two groups of patients

Patients	Duration	TT group (*n* = 33)	MP group (*n* = 31)	t value	*P* value	Cohen's d	MCID
VAS	Before surgery	6.39 ± 1.77	6.42 ± 1.63	-0.060	0.952	/	
	6 months post	3.18 ± 1.81	2.81 ± 1.49	0.907	0.368	/	
	Last follow-up	1.45 ± 0.62	1.26 ± 0.44	1.468	0.148	/	
AOFAS	Before surgery	41.27 ± 4.32	41.35 ± 4.58	-0.074	0.942	/	
	6 months post	60.97 ± 5.75	68.35 ± 6.36	-4.862	**<0.001**	**1.217**	**3**
	Last follow-up	82.48 ± 8.74	88.68 ± 4.93	-3.519	**<0.001**	**0.874**	**5**
ROM (°)	Before surgery	10.09 ± 1.81	10.03 ± 1.83	0.129	0.898	/	
	6 months post	11.82 ± 2.93	16.16 ± 3.01	-5.840	**<0.001**	**1.461**	**2**
	Last follow-up	29.52 ± 4.34	35.06 ± 3.76	-5.478	**<0.001**	**1.463**	**3**

The bold words in the chart indicate statistical significance

VAS, visual analog scale; AOFAS, American Foot Surgery Association ankle-hindfoot score; ROM, range of motion; MP, miniplate; TT, traditional treatment the steel plate was exposed, and the wound healed after negative pressure suction with vacuum sealing drainage. There were no complications such as incision infection, lower limb deep venous thrombosis, loss of reduction, or plate fracture. Traumatic arthritis and joint stiffness were observed in both groups during the follow-up period. At the last follow-up, ischemic necrosis of bone fragments occurred in two patients in the TT group, but not in the MP group. One of the patients was scheduled for follow-up revision surgery.

Discussion

Type-C3 pilon fractures are complex fractures of the articular surface and metaphysis, and the treatment effect is often unsatisfactory. Reconstruction of the smooth joint surface, reduction in the occurrence of complications, restoration of the line of force of the lower extremities, and maintaining ankle joint stability are still some of the great challenges faced by foot and ankle surgeons [13]. Blauth et al. proposed the 3P principle for the treatment of pilon fractures: protecting the vitality of the bone and soft tissue, anatomic reduction, and providing fixation to meet the early movement of the ankle joint [14]. Therefore, according to the characteristics of type-C3 pilon fracture, the choice of suitable posture, good incision, proper reduction sequence, appropriate internal fixation, soft tissue protection, postoperative management, and effective rehabilitation exercises are all indispensable parts of treatment [15–17]. Sufficient research has been conducted on the choice of the incision approach for C3 pilon fractures. The mainstream approach is anterolateral combined with the posteromedial approach [15, 18]. When the operator fully exposes the fracture end in the face of the comminuted metaphysis and articular surface, reduction and internal fixation are the most important problems. Based on the anatomical characteristics of the ankle, Chen et al. proposed a new four-column theory for the treatment of type-C3 pilon fracture and regarded the fibula as a separate external column. The posterior part of the intermalleolar line is the posterior column, and the anterior part of the intermalleolar line is the anterior column. The reduction sequence has been suggested to include the lateral, posterior, medial, and anterior columns [9]. To obtain an effective reduction and prevent height loss, it is often necessary to put in 3–4 steel plates, which inevitably lead to serious complications such as soft tissue peeling. In this study, the choice of a micro-steel plate combined with a main steel plate has obvious advantages.

Miniature steel plates are widely used for the middle foot and have a wide range of indications, good biomechanical properties, and high holding force [19]. The application of type-C3 pilon fracture can fix a larger bone mass at the fracture end and reduce the difficulty of the surgery. In addition, a miniature steel plate can provide a larger contact area, which can reduce the occurrence of valgus deformity to a certain extent, in patients who have difficulty in restoring cortical alignment to achieve the supporting effect. If peeling is minimized during the surgery, it has limited effect on the surrounding soft tissues. The steel plate and screw lock are integrated, and the angle stability of the locking screw disperses the stress in each component, reducing the reset loss and providing high stability, which is beneficial for early functional forging [20]. According to the Burwell-Charenley radioactive reduction standard, the reduction effect of the miniplate combined with the main plate in this study was also satisfactory. The excellent rate of resetting in MP group was as high as 96.8%. This is due to the use of miniplates to simplify the reduction procedure, gradually changing the complicated and difficult C3 type to B type or even A type. However, the traditional treatment method is difficult to maintain after reduction, and it is easy to lose the reduction material after implantation, which wastes the operation time. Therefore, the use of miniplate can not only improve the excellent rate of fracture reduction, but also shorten the operation time. Besides, Traditional open reduction and internal fixation for type-C3 pilon fractures involve high-volume implants. Some researchers consider that these strong implants act as bridge plates and that it is ideal to form calluses through endochondral ossification in the epiphyseal region [21–23]. Some researchers consider that this leads to a rigid environment and a reduction in callus formation [22]. According to the callus formation of 6 weeks postoperative mRUST, it was only 30.3% in the TT group, compared with 64.5% in the MP group, which indicates that the use of micro plate can reduce the implant volume while obtaining strong internal fixation, which is conducive to the formation of callus. Furthermore, the results of this study also showed that the postoperative AOFAS score and ankle ROM of the MP group were significantly higher than those of the TT group($P<0.05$). Therefore, the use of miniature steel plates combined with the main steel plates can effectively reduce the volume of the ankle joint, help patients to exercise, and restore ankle joint function. Several scholars have investigated pilon fractures. Penny et al. proposed that the use of a single main plate in bridging mode is not durable and cannot fully deal with joint fragments. Multiple implants and supplementary double-column plates should be used to treat pilon fractures and to provide additional mechanical support for the epiphyseal region. However, postoperative follow-up imaging examinations have shown that the rate of fracture healing in patients with high internal implant levels is extremely slow [23]. Van Rysselberghe et al. pointed out that the structure of multiple steel plates may be extremely large, working duration may be long, or mechanical environment of the implant may be asymmetric [22]. Campbell et al. proposed the idea of contralateral cortical replacement plate therapy and compared patients treated with contralateral cortical replacement plates and those with single implants. Although there was no significant difference in the reoperation rate between the two groups, patients who received a single implant healed faster and had sufficient anti-fatigue ability to remain intact throughout the healing process [24]. Although it is uncertain whether steel plate supplementation has a negative effect on the healing of pilon fractures, a study has found that more screw numbers and higher screw density at the fracture site have a higher risk for failure, and that screw density between 0.4 and 0.5 is an independent protective factor to prevent reoperation [24, 25]. The results of this study support the argument that patients treated with a microplate combined with a main plate have a higher healing rate than those who undergo traditional surgeries. The miniature plate is easy to reduce, which not only reduces the screw density, but also reduces the volume of the implant and reduces the incidence of complications such as incision infection and non-union to a certain extent. In addition, the data from this study support that the combination of mini-plates for C3 Pilon fractures does not increase financial stress in patients. This study has certain limitations, including the inherent weaknesses of retrospective studies and the small sample size, which may lead to certain errors in the analysis. A large number of samples and prospective studies are still needed for further verification. In addition, there are limitations related to data retrieval, including variability in data collection protocols across different place and time periods.

Conclusions

Miniplates combined with main plates can effectively treat C3 pilon fractures without increasing soft tissue dissection, incision length, and duration of surgery and have obvious advantages in terms of reduction, stability, and complications. In future work, we need studies with larger sample sizes and longer follow-up times. Long-term complications, especially traumatic arthritis and fracture non-union. In addition, in the follow-up work, limited internal fixation combined with Kirschner wire fixation should be attempted to further reduce the use of internal implants, which is conducive to early functional exercise.

Abbreviations

VAS	Visual analog scale
AOFAS	American foot surgery association ankle-hindfoot score
ROM	Range of motion
MP	Miniplate
TT	Traditional treatment
mRUST	Modified radiographic union scale for tibial fractures

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Author contributions

JZ developed the idea of the study. QZ participated in its design and helped draft the manuscript. QZ, HY, CY, YX, and YY contributed to data acquisition and interpretation. QZ revised the manuscript. All authors have read and approved the final version of the manuscript. JZ and HY contributed equally to this work. QZ and YX contributed equally.

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Data availability

Data is provided within the manuscript or supplementary information files.

Declarations

Ethics approval and consent to participate

This study was approved by the Ethics Committee of the Second Affiliated Hospital of Anhui Medical University and all patients provided informed consent.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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