Modified minimally invasive anteromedial approach with cannulated screw fixation for medial malleolus fracture: A novel technique

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Abstract

Background: In the treatment of medial malleolus fracture with traditional anteromeal ankle incision, the skin incision is larger and the incision-related complications are more. This study aims to explore the efficacy of this minimally invasive approach in the treatment of medial malleolus fracture.

Methods: A retrospective analysis the patients with ankle fracture who were treated with modified minimally invasive anteromedial approach (MMITAA group) in our hospital between January 2019 and April 2020, and patients with ankle fracture treated with traditional anteromedial approach (TAA group) between January 2018 and December 2019. After regular follow-up, perioperative period, follow-up and imaging data of the two groups were compared to evaluate whether the therapeutic effect of the modified approach was better than that of the traditional approach.

Results: The preoperative VAS score was 6.89 ± 1.74 in the MMIAA group and 7.17 ± 1.06 in the TAA group ($P > 0.05$). The VAS score in the MMIAA group was 4.97 ± 1.10 at 3 days after the surgery, which was significantly lower than the 6.20 ± 0.92 in the TAA group. The VAS score at 1 month after the surgery was still lower in the MMIAA group than in the TAA group.According to the results of postoperative ankle CT, the maximum postoperative step-off of the articular surface was 0.14 ± 0.12 mm in the MMIAA group and 0.18 ± 0.18 mm in the TAA group, but the difference was not statistically significant. The postoperative AOFAS score was 95.95 ± 6.81 points in the MMIAA group and 93.99 ± 8.74 points in the TAA group, which was slightly higher in the MMIAA group than in the TAA group, with no significant difference. Of the four subjective scores included in the AOFAS, the pain score of 38.15 ± 3.90 in the MMIAA group was significantly lower than the 36.51 ± 5.03 in the TAA group.All patients achieved fractrue healing.

Conclusions: The modified minimally invasive anteromedial approach greatly shortened the lenth of incision, thereby reducing the incidence of incision-related complications, by smaller trauma achieve the same clinical effect.

Introduction

Ankle fracture is one of the most common clinical injuries, accounting for approximately 9% of all body fractures. With society ageing, the incidence of ankle fracture is increasing annually, and ankle fractures have thus become a hot spot of clinical research[1][2]. Medial malleolus fractures can exist alone or in combination with lateral malleolus and posterior malleolus fractures; all of these fractures are types of ankle injury. For displaced ankle fractures, reconstruction of the ankle mortise by surgical open reduction and internal fixation is the widely recognized standard treatment[3]. Although there have been many controversies in the academic community about the treatment of medial malleolus injuries, for displaced medial malleolus fractures, surgical treatment with anatomical reduction and rigid fixation is preferred by most orthopaedic surgeons[4][5].A recent biomechanical study by Lareau et al.[6] showed that for displaced medial malleolus fractures, compared with conservative treatment, anatomical reduction and internal fixation reduced the pressure on the medial malleolus articular surface by 27.8%. This result further confirms the importance of reduction and fixation of the medial malleolus.

In recent years, to reduce the stimulation of weak soft tissues around the ankle joint and reduce the occurrence of soft tissue-related complications, minimally invasive treatment has gradually become a trend in foot and ankle injury treatment [7]. Advances in minimally invasive techniques have led to their application in the treatment of ankle fractures, such as the use of fibular intramedullary nails [8][9]. Fibular intramedullary nail technology not only greatly reduces surgical trauma and the incidence of incision complications but also provides better biomechanical stability.

With the widespread application of minimally invasive techniques for lateral malleolus fractures, medial incision-related complications have gradually become more prominent. At present, 30% of ankle incision-related complications are from medial incisions[10]. Many investigators have evaluated minimally invasive techniques to resolve the issue of medial malleolus incision complications. Although these techniques can reduce incision-related complications to a certain extent, several problems remain, such as limited visual field, difficulty of reduction, and limited indications [[11][12].

In this study, we modified existing procedures based on the traditional anteromedial approach to design a modified minimally invasive anteromedial approach. This approach minimizes soft tissue irritation while allowing reduction and fixation of the articular surface under direct vision, which is widely suitable for transverse or oblique fractures of the medial malleolus caused by mechanisms such as pronation–external rotation and supination–external rotation, the most common medial malleolus fractures. This study aims to explore the efficacy of this minimally invasive approach.

Method

1. Patient data and methods

Patients with ankle fractures who were admitted to the Trauma Emergency Center of the Third Hospital of Hebei Medical University, China, from January 2019 to April 2020 were included in this study. Standard anteroposterior and lateral radiographs of the ankle and preoperative computed tomography (CT) images of the ankle were collected for all patients. The inclusion criteria were age 18-65 years and displaced medial malleolus fracture with or without lateral malleolus or posterior malleolus fracture. The exclusion criteria were as follows: 1. open ankle fractures; 2. other fractures or severe injuries of the ipsilateral lower limb; 3. Herscovici medial malleolus classification type A; 4. Herscovici medial malleolus classification type D; 5. severe medical diseases or other contraindications to surgery. All enrolled patients were treated with a modified minimally invasive anteromedial approach that used cannulated screw fixation for medial malleolus fractures. All patients signed the informed consent form for surgery, and a designated person conducted postoperative follow-up and collected the relevant clinical data of the patient.

In addition, patients with ankle fractures who were admitted to our hospital and underwent surgical treatment from January 2018 to December 2018 were included. The inclusion criteria were as follows: 1. age 18-65 years; 2. displaced medial malleolus fracture with or without lateral malleolus or posterior malleolus fracture; 3. traditional anteromedial approach for medial malleolus fractures and cannulated screws for fixation. The exclusion criteria were as follows: 1. open ankle fracture; 2. other fractures or severe injuries of the ipsilateral lower limb; 3. medial malleolus classification type A; 4. Herscovici medial malleolus classification type D; 5. severe medical diseases or other contraindications to surgery. The clinical data of the patients were collected by follow-up appointment, telephone follow-up, and looking up case data. The differences in efficacy between the two groups were analysed. The protocol of this study was approved by the Ethics Committee of Hebei Medical University.(Table 1)

2. Surgical Technique

a. Spinal anaesthesia was used. After successful anaesthesia, the patient was placed in the supine position on the operating table. Disinfection with iodine alcohol and sterile draping were performed. The methods of fixation of the lateral malleolus, posterior malleolus, and distal tibiofibular joint are not described here. This section only details the modified minimally invasive anteromedial approach for the treatment of medial malleolus fractures:

b. Skin incision

The skin incision for the modified minimally invasive anteromedial approach started at the intersection of the tibialis anterior tendon and the ankle joint and ended at the tip of the medial malleolus.(Figure 1a 1b)

c. Exposure and reduction method:

The skin and the subcutaneous tissue were cut and gently separated, and the saphenous nerve and great saphenous vein were exposed and appropriately dissected. At this time, the approach was divided into the anterior and posterior windows, with the great saphenous vein as the demarcation line. First, the great saphenous vein and saphenous nerve were retracted anteriorly, and the fracture end was exposed by dissection through the posterior window. (Figure 2a 2b) The involved periosteum and hematoma were cleaned so that the fracture line was clear. The great saphenous vein and nerve were then retracted posteriorly to expose the anterior window.(Figure 3a 3b) Limited incision of soft tissue and the joint capsule in front of the medial malleolus was performed through the anterior window to expose the medial malleolus articular surface, the medial fornix of the tibiotalar joint, and part of the talar articular surface. The medial malleolus articular surface could be precisely reduced through the anterior window. The quality of anterior and lateral cortical reduction (the articular surface, anterior cortex, and lateral cortex were simultaneously visible, and flip displacement and rotational displacement could be completely avoided) was confirmed by switching the anterior and posterior windows. If free bone fragments were present, they could also be removed under direct vision. Furthermore, talar articular surface injuries could be treated through the anterior window if necessary.

d. Fixation technique

After confirming the anatomical reduction of the medial malleolus through the anterior and posterior windows, two guide pins perpendicular to the medial malleolus fracture line were inserted for fixation. After making an opening with a cannulated drill, two cannulated screws were used for fixation and compression. Intraoperative C-arm fluoroscopy was used to confirm the quality of reduction. At the same time, it could be confirmed through the anterior window that the cannulated screws did not cut into the joint.(Figure 4a~4j)

3. Postoperative treatment

After surgery, the affected limb was raised, and intravenous antibiotics were given for 24 hours for anti-infective treatment. On the second day after the surgery, the patient was instructed to perform non-weight-bearing functional exercises of the knee and ankle joints to avoid foot drop and joint dysfunction after the patient's pain had decreased significantly and become tolerable. Two to three months after the surgery, according to the patient's X-ray results, the patient was instructed to ease into partial weight-bearing functional exercise under the protection of crutches. According to the fracture healing evident on X-ray re-examination, the patient was instructed to perform full weight-bearing functional exercise.

4. Efficacy evaluation

Patient-related complications and functional recovery were recorded at outpatient follow-up appointments. The pain visual analogue scale (VAS) was used to assess the pain of the patients on the day before surgery, 3 days after surgery, and 1 month after surgery. The American Orthopaedic Foot and Ankle Society (AOFAS) score was used to evaluate the functional recovery of the patients during their follow-up visit at 12 months.

5. Statistical methods

SPSS 19.0 (SPSS Company, USA) was used for statistical analysis. The measurement data generated in this study are expressed as the mean ± standard deviation and were compared by the paired t-test. $P < 0.05$ was considered statistically significant.

Results

A total of 92 patients with medial ankle fractures who met the criteria were included in this study from January 2019 to April 2020. All were treated with the modified minimally invasive anteromedial approach for medial malleolus fracture reduction and fixation with cannulated screws (MMIAA group). Another 86 patients with ankle fractures who were treated at our hospital from January 2018 to December 2018 and met the relevant inclusion criteria were included in the control group. All patients in the control group were treated with the traditional anteromedial approach (TAA group) for the exposure and reduction of the fracture and for fixation with cannulated screws. The mean follow-up time was 25.6 months (14-29 months) for the MMIAA group and 36.5 months (30-41 months) for the TAA group. In the MMIAA group, there were 55 males and 37 females with a mean age of 42.02 ± 10.94 years (range, 19-63 years). According to the Herscovici classification, there were 55 cases of type B and 37 cases of type C. In the TAA group, there were 40 males and 46 females with a mean age of 43.09 ± 10.10 years (range, 21-58 years). Under the Herscovici classification, there were 47 cases of type B and 39 cases of type C. There were no significant differences in sex, age, classification, or time from injury to surgery between the two groups. The mean operation time was 65.32 ± 6.45 min for the MMIAA group and 66.94 ± 5.84 for the TAA group ($P > 0.05$). The average blood loss was 79.67 ± 20.13 ml in the MMIAA group and 118.72 ± 25.06 ml in the TAA group ($P < 0.05$). The average length of the medial malleolus incision in the MMIAA group was 3.56 ± 0.44 cm, which was significantly shorter than that in the TAA group (7.32 ± 0.87 cm).

None of the 92 patients in the MMIAA group had medial incision–related soft tissue complications, but four patients (6.98%) in the TAA group had medial incision–related complications, including skin edge necrosis or superficial infection. Two complications were relieved by oral or intravenous administration of antibiotics, and the other two patients returned to the operating room for debridement and eventually healed without removal of the internal fixation. All patients in the two groups finally achieved bone union without other related complications, and there were no cases of internal fixation failure.(Table 1)

Table 1 General data of patients in MMIAA group and TAA group

Grouping	Number of cases	Age (years)	Sex		Herscovici classification		Time from injury to surgery (days)	Operation time min	Blood loss volume ml	Incision length cm
			Male	Female	Type B	Type C				
MMIAA group	92	42.02 ± 10.94	55	37	55	37	5.00 ± 2.02	65.32 ± 6.45	79.67 ± 20.13	3.56 ± 0.44
TAA group	86	43.09 ± 10.10	40	46	47	39	5.02 ± 1.46	66.94 ± 5.84	118.72 ± 25.06	7.32 ± 0.87
Statistic value		- 0.679	0.717		0.478		- 0.159	-1.760	-11.50	-36.68
P value		0.498	0.397		0.489		0.873	0.08	0.00	0.00

The preoperative VAS score was 6.89 ± 1.74 in the MMIAA group and 7.17 ± 1.06 in the TAA group ($P > 0.05$). The VAS score in the MMIAA group was 4.97 ± 1.10 at 3 days after surgery and was significantly lower than the VAS score in the TAA group, which was 6.20 ± 0.92. At 1 month after surgery, the VAS score was still lower in the MMIAA group than in the TAA group. (Table 2) According to the results of postoperative ankle CT, the maximum postoperative step-off of the articular surface was 0.18 ± 0.18 mm in the MMIAA group and 0.14 ± 0.12 mm in the TAA group, but the difference was not statistically significant. (Table 3) The postoperative AOFAS score was 95.95 ± 6.81 points in the MMIAA group and 93.99 ± 8.74 points in the TAA group, but the difference between these two scores was not significant. Of the four subjective scores included in the AOFAS, the pain score of 38.15 ± 3.90 in the MMIAA group was significantly lower than the pain score of 36.51 ± 5.03 in the TAA group.(Table 4)

Table 2 Comparison of VAS score between the two groups

Group	VAS score		
	1 day before surgery	3 days after surgery	1 month after surgery
MMIAA group	6.89 ± 1.74	4.97 ± 1.10	1.54 ± 2.33
TAA group	7.17 ± 1.06	6.20 ± 0.92	2.16 ± 1.21
Statistic value	1.316	8.054	2.246
P value	0.190	0.001	0.026

Table 3 Comparison of postoperative maximum articular surface displacement between the two groups

Group	Postoperative maximum articular surface step-off (mm)
MMITAA group	0.14 ± 0.12
TAA group	0.18 ± 0.18
Statistic value	1.869
P value	0.063

Table 4 Comparison of AOFAS score between the two groups

Group	AOFAS score				
	Total score	Pain score	Activity restrictions	Walking distance	Walking pavement
MMIAA group	95.95 ± 6.81	38.15 ± 3.90	9.02 ± 1.41	4.71 ± 0.46	4.63 ± 0.78
TAA group	93.99 ± 8.74	36.51 ± 5.03	9.20 ± 1.50	4.72 ± 0.75	4.65 ± 0.76
Statistic value	1.326	2.345	- 1.090	- 1.788	0.179
P value	0.185	0.019	0.276	0.074	0.858

Discussion

The incidence of ankle fractures is as high as 187/10000, making it one of the most common types of fracture requiring surgical treatment [13]. Many factors are responsible for ankle fractures, but sprains (associated with falls or sports) are always the most common injurious factor underlying ankle fractures [13]. Fractures of the medial malleolus, which is part of the ankle joint, typically occur as part of ankle joint fracture, and the incidence of medial malleolus fracture alone is low [14]. The medial malleolus was considered the most important structure for maintaining ankle stability until a 1979 study by Yablon et al. [15] overturned this idea and shifted the focus of surgeons' attention to the lateral malleolus. After being overlooked for many years, recent reports have renewed the significance of the bony structures of the medial malleolus for ankle stability [6].

To reduce the risk of incision-related complications, minimally invasive techniques are now the direction of development of ankle fracture treatments. Attempts have been made to use the percutaneous prying technique for the reduction and fixation of medial malleolus fractures. This technique effectively reduces soft tissue irritation and significantly reduces the occurrence of incision-related complications. Nonetheless, the quality of percutaneous fixation and reduction is suboptimal, and delayed union and nonunion are likely to occur due to embedding of soft tissue in the fracture end [11]. Reduction and fixation of medial malleolus fractures by using minimally invasive methods with the help of arthroscopy has also been assessed, but due to its steep learning curve and difficulty in performing reduction, there are only a few reports on the treatment of medial malleolus fractures alone [12].In addition, due to the relative lack of data for this technique compared with the amount of data on open reduction surgery, its efficacy has yet to be further confirmed. To minimize invasiveness under the premise of anatomical reduction, we modified the traditional anteromedial approach. This new modified minimally invasive anteromedial approach can effectively reconstruct the medial malleolus cortex and articular surface. The purpose of this study was to compare the efficacy of the modified minimally invasive anteromedial approach with that of the traditional anteromedial approach in the treatment of medial malleolus fractures and assess the effectiveness of the new approach.

The range of indications determines the clinical value of minimally invasive techniques to some extent. The Lauge-Hansen classification is the most traditional classification of ankle fractures based on the mechanism of injury and is by far the most widely used classification in clinical practice [16][17]. According to the Lauge-Hansen classification, supination external rotation and pronation external rotation are the most common injury mechanisms of the ankle joint, and external rotation injuries also account for the vast majority of ankle fractures [16].Studies of the morphology of medial malleolus fractures have shown that external rotation injury (including pronation external rotation and supination external rotation)–associated medial malleolus fractures mostly result from deltoid ligament tears, and the morphology of their fracture lines is often transverse or oblique [18]. Transverse or oblique medial malleolus fractures often manifest radiographically as Herscovici type B or C, both of which can be reduced by our modified minimally invasive anteromedial approach and fixed with cannulated screws. Among medial malleolus fractures, transverse fractures account for 57% and are associated with supination external rotation injuries, and oblique fractures account for 26% and are associated with pronation external rotation injuries; together, the two fracture types account for 83% of all medial malleolus fractures[18]. Therefore, the modified anterolateral approach can be used to treat the vast majority of medial malleolus fractures, especially for Herscovici types B and C. For medial malleolus fractures with vertical fracture lines (Herscovici type D), the mechanism of injury is related to supination adduction injury. Although the fracture cannot be fixed through this incision, it can be reduced by the modified minimally invasive anteromedial approach followed by cannulated screw fixation. This minimally invasive approach is inapplicable only to a very few posterior colliculus fractures and comminuted fractures.

In addition, if external rotation ankle injury is accompanied by ankle dislocation, it often leads to severe soft tissue injury and even skin necrosis of the medial ankle due to the tension of medial soft tissue and the stimulation of medial ankle fracture end, thereby increasing the risk of surgical incision complications. This minimally invasive surgical approach enters from the anterior medial ankle, which perfectly avoids the injury area of the medial ankle, and is especially suitable for most ankle fractures with poor soft tissue conditions. It effectively decreases the risk of surgical complications, reduces the effect of soft tissue injury on the timing of surgery, allows early surgical fixation, shortens treatment time and improves the comfort of patients..(Figure 5a 5b)

The traditional anteromedial approach is the most widely used approach for the treatment of medial malleolus fractures, and its skin incision is at least 10 cm long. Usually, an incision is made centred on the medial malleolus along the long axis of the limb, with the distal arc towards the front of the medial malleolus [19]. This approach has been widely used in clinical practice because it adequately exposes the fracture line, allows the removal of embedded soft tissue and hematoma at the fracture end, and reduces the medial malleolus cortex under direct vision. Because the front of the incision coincides with the course of the great saphenous vein and saphenous nerve, some doctors are accustomed to moving this approach posteriorly to avoid injury. Moving the incision posteriorly does effectively avoid nerve and vein injury but also increases the difficulty of exposing the articular surface of the medial malleolus. The quality of articular surface reduction can only be judged by the anatomical reduction of the lateral cortex[20]. By using arthroscopic exploration, Swart et al. [21] demonstrated that even with satisfactory cortical reduction, there may still be a large displacement of the articular surface of the medial malleolus, so it is not reliable to judge articular surface reduction using the cortex. In particular, when the fracture involves the medial fornix (plafond margin) of the tibial articular surface, satisfactory joint reduction can only be obtained by reducing the articular surface under direct vision to avoid the occurrence of long-term traumatic arthritis. To reduce the articular surface under direct vision, some scholars have tried to make the posterior arc of the traditional anteromedial approach into a "J" shape, which can effectively expose the articular surface and cortex and ensure the quality of reduction[20]. Unfortunately, it also increases the length of the incision and increases the likelihood of incision-related complications.

To minimize the incision length and reduce the irritation of soft tissue under the premise of ensuring the quality of reduction, we designed a modified minimally invasive anteromedial approach. This approach uses the great saphenous vein and saphenous nerve as the separator to generate anterior and posterior windows. Through the anterior window, the articular surface can be precisely reduced, especially when the fracture line of a Herscovici type C fracture is located at the level of the medial fornix of the tibial articular surface. After anatomical reduction of the joint, temporary fixation can be performed using fine Kirschner needles perpendicular to the joint fracture line to maintain the position. Then, the quality of reduction of the anterior and lateral cortices is observed through the posterior window to avoid any rotation, varus, or valgus. After confirming a satisfactory reduction, cannulated screws are used to fix the fracture. The anterior window allows confirmation of not only the quality of joint reduction but also whether the cannulated screws cut into the joint, thus reducing the need for intraoperative fluoroscopy. Furthermore, the presence of cartilage injury on the articular surface of the talus can be observed through the anterior window; if necessary, free cartilage fragments can be removed, and microfractures can even be performed to treat articular cartilage injury [22].

The analysis of the postoperative CT results in this study showed that the maximum postoperative articular surface displacement in the MMIAA group was 0.14 ± 0.12 mm, similar to the value of 0.18 ± 0.18 mm in the TAA group ($P > 0.05$). This indicates that the effect of joint reduction performed by the modified minimally invasive anteromedial approach is not inferior to that of the traditional anteromedial approach.

Minimally invasive incision can effectively reduce the incidence of incision-related complications, especially for patients with poor local soft tissue conditions due to diabetes, smoking, peripheral vascular disease, or trauma [23]

[24]. In this study, the mean incision length in the MMIAA group was only 3.56 ± 0.44 cm, while the mean incision length in the TAA group was 7.32 ± 0.87 cm, so MMIAA significantly reduced the surgical incision length. The intraoperative blood loss was also lower in the MMIAA group. According to the follow-up data, no incision-related complications occurred in the MMIAA group, while the incidence of soft tissue complications was 6.98% in the TAA group. This result suggests that the application of MMIAA effectively reduces soft tissue irritation and reduces the incidence of incision-related complications. None of the patients in the MMIAA group had complications of the great saphenous vein or nerve injury, although this incision approach intersects with the vein and nerve course. This may be because the great saphenous vein and nerve are located in the centre of the incision and are sufficiently freed, better enabling their protection during reduction and fixation. In addition, the VAS scores of patients in the MMIAA group were significantly better than those in the TAA group 3 days after surgery and remained better at 1 month. This minimally invasive approach effectively reduces postoperative pain and is also conducive to the implementation of early postoperative functional exercise in patients. Eveline Bijlard et al.[25] proposed in a review that the length of the surgical incision and soft tissue irritation are both triggers of intractable scar pain after surgery. Therefore, the minimally invasive approach can improve short-term postoperative pain and may reduce long-term intractable scar pain, promote joint functional recovery, and increase patient satisfaction. In addition, the operation time was shorter in the MMIAA group than in the TAA group, suggesting that the MMIAA technique is simple, without a steep learning curve, and will be easier to promote in clinical practice than the arthroscopic minimally invasive technique. The lack of a significant difference in operating time between the two groups may reflect the fact that most of the cases were not simple medial malleolus fractures; thus, the operating time for other fractures may have interfered with the final results.

The AOFAS scores at 12 months after operation were similar: 95.95 ± 6.81 in the MMIAA group and 93.99 ± 8.74 in the TAA group. This demonstrates that the use of a modified minimally invasive anteromedial approach for the treatment of medial malleolus fractures can achieve similar therapeutic results as the traditional anteromedial approach. Comparing the various indicators in the AOFAS score showed that the AOFAS score was slightly higher in the MMIAA group than in the TAA group, mainly due to the pain score in the subjective score section. The small surgical scar of MMIAA reduces the discomfort caused by the friction between the scar near the joint and shoes and socks, which may be an important reason for the high score.

Limitations

This study has some limitations: 1. It was a single-centre retrospective study, which reduces its generalizability. A more precisely designed prospective study is needed to further verify the feasibility of this minimally invasive approach. 2. It had a short follow-up time and thus could not evaluate the effect of anatomical reduction of the medial malleolus articular surface on long-term outcomes. 3. The cases included were not simple medial malleolus fractures, so other injuries may have interfered with the study results.

Conclusion

The modified minimally invasive anteromedial approach can reduce the medial malleolus articular surface and medial malleolus cortex under direct vision through two windows and can effectively protect the great saphenous vein and nerve. MMIAA is minimally invasive, has a low incidence of complications, and is associated with mild postoperative pain and rapid recovery. In addition, this technique is simple to perform and has a short learning curve. It is an ideal choice for the treatment of Herscovici type B and C fractures.

Abbreviations

MMIAA: minimally invasive anteromedial approach;

TAA: traditional anteromedial approach;

VAS: Visual analog scale;

AOFAS: American Orthopaedic Foot and Ankle Society.

Declarations

Acknowledgements

Not applicable.

Authors' contributions

TZ and YDQ conceived the study. TZ provided the materials and samples. TZ and YDQ contributed to the data collection, analysis and interpretation of the results, and writing of the manuscript. TZ provided administrative support. All authors read and approved the final manuscript and consented to publish this manuscript.

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Availability of data and materials

All data generated or analyzed during this study are included in this article.

Ethics approval and consent to participate

The study was approved by the ethical committee of The Third Hospital of Hebei Medical University (K2015-001–12), and all methods were carried out in accordance with relevant guidelines and regulations/Declaration of Helsinki.Informed consent obtained from their parents or legal guardian.

Consent for publication

Not applicable.

Competing interests

All authors declare no potential confict of interest.

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References

1 Court-Brown CM, Caesar B. Epidemiology of adult fractures: A review. Injury 2006, 37(8): 691-697.

2 Kannus P, Palvanen M, Niemi S, Parkkari J, Jarvinen M. Increasing number and incidence of low-trauma ankle fractures in elderly people: Finnish statistics during 1970-2000 and projections for the future. Bone 2002, 31(3): 430-433.

3 Vander GR, Michelson JD, Bone LB. Fractures of the ankle and the distal part of the tibia. Instr Course Lect 1997, 46: 311-321.

4 Bulut T, Gursoy M. Isolated Medial Malleolus Fractures: Conventional Techniques Versus Headless Compression Screw Fixation. J Foot Ankle Surg 2018, 57(3): 552-556.

5 Pagliaro AJ, Michelson JD, Mizel MS. Results of operative fixation of unstable ankle fractures in geriatric patients. Foot Ankle Int 2001, 22(5): 399-402.

6 Lareau CR, Bariteau JT, Paller DJ, Koruprolu SC, Digiovanni CW. Contribution of the medial malleolus to tibiotalar joint contact characteristics. Foot Ankle Spec 2015, 8(1): 23-28.

7 Ashman BD, Kong C, Wing KJ, Penner MJ, Bugler KE, White TO, et al. Fluoroscopy-guided reduction and fibular nail fixation to manage unstable ankle fractures in patients with diabetes: a retrospective cohort study. Bone Joint J 2016, 98-B(9): 1197-1201.

8 White TO, Bugler KE, Appleton P, Will E, Mcqueen MM, Court-Brown CM. A prospective randomised controlled trial of the fibular nail versus standard open reduction and internal fixation for fixation of ankle fractures in elderly patients. Bone Joint J 2016, 98-B(9): 1248-1252.

9 Smith G, Mackenzie SP, Wallace RJ, Carter T, White TO. Biomechanical Comparison of Intramedullary Fibular Nail Versus Plate and Screw Fixation. Foot Ankle Int 2017, 38(12): 1394-1399.

10 Zalavras CG, Christensen T, Rigopoulos N, Holtom P, Patzakis MJ. Infection following operative treatment of ankle fractures. Clin Orthop Relat Res 2009, 467(7): 1715-1720.

11 Weinraub GM, Levine P, Shi E, Flowers A. Comparison of Medial Malleolar Fracture Healing at 8 Weeks After Open Reduction Internal Fixation Versus Percutaneous Fixation: A Retrospective Cohort Study. J Foot Ankle Surg 2017, 56(2): 277-281.

12 Liu C, You JX, Yang J, Zhu HF, Yu HJ, Fan SW, et al. Arthroscopy-Assisted Reduction in the Management of Isolated Medial Malleolar Fracture. Arthroscopy 2020, 36(6): 1714-1721.

13 Daly PJ, Fitzgerald RJ, Melton LJ, Ilstrup DM. Epidemiology of ankle fractures in Rochester, Minnesota. Acta Orthop Scand 1987, 58(5): 539-544.

14 Lokerman RD, Smeeing D, Hietbrink F, van Heijl M, Houwert RM. Treatment of a Scientifically Neglected Ankle Injury: The Isolated Medial Malleolar Fracture. A Systematic Review. J Foot Ankle Surg 2019, 58(5): 959-968.

15 Yablon IG, Heller FG, Shouse L. The key role of the lateral malleolus in displaced fractures of the ankle. J Bone Joint Surg Am 1977, 59(2): 169-173.

16 Yde J. The Lauge Hansen classification of malleolar fractures. Acta Orthop Scand 1980, 51(1): 181-192.

17 Lange H. [Significance of Lauge-Hansen's classification for the roentgen diagnosis of malleolar fractures]. Beitr Orthop Traumatol 1972, 19(6): 319-324.

18 Ebraheim NA, Weston JT, Ludwig T, Moral MZ, Carroll T, Liu J. The association between medial malleolar fracture geometry, injury mechanism, and syndesmotic disruption. Foot Ankle Surg 2014, 20(4): 276-280.

19 Saini P, Aggrawal A, Meena S, Trikha V, Mittal S. Miniarthrotomy assisted percutaneous screw fixation for displaced medial malleolus fractures - A novel technique. J Clin Orthop Trauma 2014, 5(4): 252-256.

20 Carter TH, Duckworth AD, White TO. Medial malleolar fractures: current treatment concepts. Bone Joint J 2019, 101-B(5): 512-521.

21 Swart EF, Vosseller JT. Arthroscopic assessment of medial malleolar reduction. Arch Orthop Trauma Surg 2014, 134(9): 1287-1292.

22 Savage-Elliott I, Ross KA, Smyth NA, Murawski CD, Kennedy JG. Osteochondral lesions of the talus: a current concepts review and evidence-based treatment paradigm. Foot Ankle Spec 2014, 7(5): 414-422.

23 Wukich DK, Kline AJ. The management of ankle fractures in patients with diabetes. J Bone Joint Surg Am 2008, 90(7): 1570-1578.

24 Soohoo NF, Krenek L, Eagan MJ, Gurbani B, Ko CY, Zingmond DS. Complication rates following open reduction and internal fixation of ankle fractures. J Bone Joint Surg Am 2009, 91(5): 1042-1049.

25 Bijlard E, Uiterwaal L, Kouwenberg CA, Mureau MA, Hovius SE, Huygen FJ. A Systematic Review on the Prevalence, Etiology, and Pathophysiology of Intrinsic Pain in Dermal Scar Tissue. Pain Physician 2017, 20(2): 1-13.

Figures

1a

1b

Figure 1

a Schematic diagram of the location of the modified minimally invasive anteromedial approach incision.

b. Body surface localization of modified minimally invasive anteromedial approach incision.

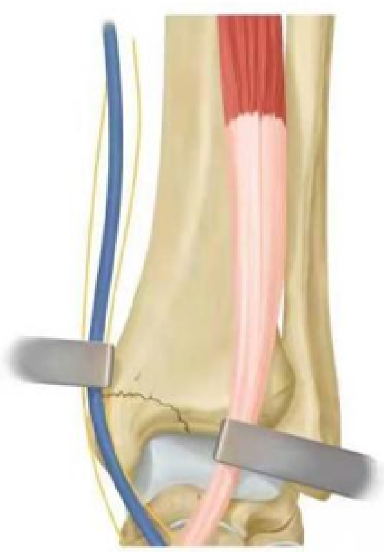
2.a

2.b

Figure 2

a Schematic diagram of the anterior window of the modified minimally invasive anteromedial approach.

b The medial fornix and the corresponding talar articular surface can be exposed through the anterior window during the surgery.



3.a

3.b

Figure 3

a Schematic diagram of the posterior window of the modified minimally invasive anteromedial approach.

b The front of the medial malleolus and lateral cortex can be exposed through the posterior window during surgery, and the entry point of the cannulated screw can be exposed at the same time.

Figure 4

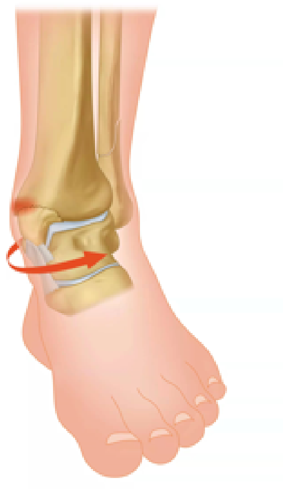
a, b Preoperative X-ray of a patient

c, d Medial malleolus fracture displacement can be seen in the preoperative CT of the patient, and the displacement is in the coronal and sagittal planes.

e, f Postoperative X-ray of the patient

g, h Anatomical reduction on the coronal and sagittal planes can be seen on the postoperative CT of the patient.

I, j Incision before and after suturing of the patient.



5a

5b

Figure 5

a External rotation ankle injury accompanied by ankle dislocation, which often leads to severe soft tissue injury and even skin necrosis.

b Modified minimally invasive anteromedial approach could perfectly avoids the injury area of the medial ankle.