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Original Article

Single-incision approach improves wound healing and bone union for treating mid-to-lower segment of tibiofibular fracture

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Abstract: The mid-to-lower segment of tibiofibular fractures (MLTFs) is commonly encountered in clinical practice, which is conventionally treated by the double-incision surgical approach. However, the double-incision approach frequently makes the closure of the wound extremely difficult and sometimes results in necrosis of skin around fractured sites. In the present study, our experience of using a single-incision surgical approach for treating MLTF was exhibited. From February 2005 to December 2013, the clinical outcomes of 212 patients with MLTFs who underwent either double-incision approach or single-incision approach were retrospectively evaluated and compared. Both groups were similar with respect to injury mechanism and all patients were followed up with the efficacies of treatment evaluated by Johner-Wruth criteria. The results demonstrated that the effective rate and the rate of excellent and good efficacy in the single-incision group were significantly higher than those in the double-incision group ($P<0.05$). In addition, the rates of skin wound healing and bone union after surgery in the single-incision group were significantly higher than those in the double-incision group ($P<0.05$). These findings indicate that the single-incision surgical approach, which holds the advantages of being milder in trauma, fewer in complications and better in function restoration, might be used as an alternative method for treating MLTFs.

Keywords: Single incision, tibiofibular fractures, internal fixation

Introduction

Most fractures that occur at the mid-to-lower segment of the leg are unstable, which require open reduction and internal fixation [1]. In general, bilateral skin incisions are adopted for exposure of mid-to-lower segment of tibiofibular fractures (MLTFs) [2]. However, the skin on the mid-to-lower segment of the leg is in direct contact with the tibial bone and lack of thick subcutaneous tissue, which would sustain severe trauma and disruption to its vascularity in case of MLTF. These often lead to delayed healing of the skin on the medial aspect of the tibia or bony non-union. It is therefore proposed that maintaining fracture stability without increasing soft tissue morbidity may be of significant importance in improving wound healing and bone union.

During the past decade, single-incision treatment has been reported with good clinical efficacy for the management of MLTFs [1]. Also, the anatomical basis of the single lateral incision for treatment of MLTFs has been performed recently [3]. The vascular network that supplies the skin and the subcutaneous soft tissue of the mid-to-lower segment of the leg has assumed a longitudinal distribution along the intermuscular septa. These suggest that the lateral one-incision approach, compared to the conventional two-incision approach, may mitigate injuries to the vascular network, thus improving wound healing and fracture union, and reducing the incidence of postoperative complications. However, the impact of single-incision approach on bone union and incidence of complication, as well as the regional or local flap choices for secondary reconstruction of

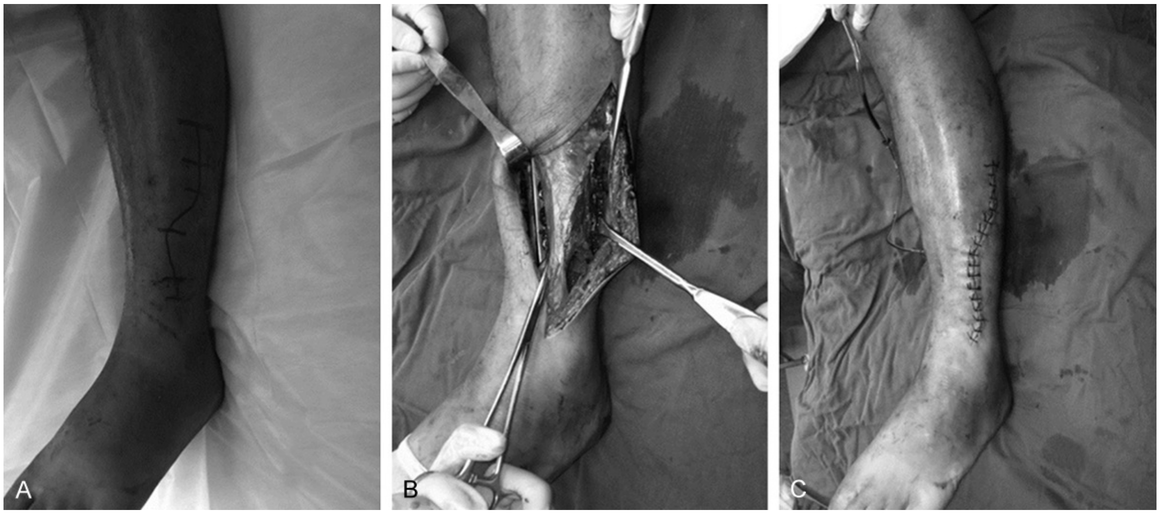

Figure 1. Design of the single-incision approach. A, B. An S-shaped linear incision with the midpoint located at the fracture side was made at the anterolateral aspect of the leg; C. The post-operative view of the wound.

Table 1. Preoperative patient demographics

	Single-incision group	Double-incision group	*P* value
Mean age	40.50 ± 15.02	39.97 ± 13.05	0.841
Gender			0.950
Male	49	45	
Female	61	57	
Fracture location			0.400
Left leg	61	56	
Right leg	49	46	
Injury mechanism			0.350
Vehicular trauma	75	69	
Fall from a height	25	18	
Other trauma	10	15	

Table 2. Comparison of operative time

	Single-incision group	Double-incision group	*P* value
Shortest time	40	45	0.000
Longest time	80	115	

potential postoperative exposure of the hardware and bones, have rarely been reported thus far.

In the present study, the efficacy of single-incision approach for treatment of MLTFs was investigated. Compared to double-incision approach, single-incision approach exhibited shorter operative time, less intra-operative blood loss, milder disruption to soft tissues, and better wound healing and bone union.

Patients and methods

This study was approved by the institutional review board of Fuzhou General Hospital (Approval No. FZGH20130712) and written informed consent was received from all enrolled patients.

From February 2005 to December 2013, 212 patients with MLTF were admitted into Department of Orthopaedics, Fuzhou General Hospital. Fractures occurred in left leg in 117 patients, right leg 95 patients. 110 patients underwent open reduction and internal fixation through single-incision approach (the single-incision group) while 102 patients underwent that through double-incision approach (the double-incision group).

Surgical procedure

After successful introduction of extradural anesthesia, the patients were placed in the supine position, sterilized routinely and draped in surgical field. For single-incision group, according to the location of the fractures, an S-shaped linear incision with the midpoint

Table 3. The rate of skin wound healing 12 days after surgery

	Single-incision group	Double-incision group	*P* value
Healed	105	92	0.000
Non-healed	5	10	

Table 4. The rate of bone union 3 months after surgery

	Single-incision group	Double-incision group	*P* value
Union	95	85	0.038
Non-union	15	17	

Table 5. Functional score of Johner-wruth criteria

	Single-incision group	Double-incision group	*Z*	*P*
Excellent	80	58	3.70	0.00
Good	18	22		
Fair	7	13		
Bad	5	9		
Total	110	102		
Rate of excellent-good efficacy	89.09%	78.43%		

located at the fracture side was made at the anterolateral aspect of the leg (without injuring the superficial peroneal nerve, **Figure 1**). After skin incision, the lateral intermuscular septum of the leg was opened, and the skin was retracted posterolaterally and the tendons retracted medially for exposure of the fibular fractured ends. After alignment, plate fixation was performed at the fibular fracture. Subsequently, the skin was retracted medially, and the tibial fracture was accessed through the space between tibialis anterior and the tibial bone. Reduction and internal fixation by the plate were then performed. After irrigation of the surgical wound by normal saline and complete coagulation of bleeding, the wounds were closed.

For double-incision group, the skin incision for accessing the tibia was made at the anterolateral or anteromedial aspect of the lower leg. The skin incision for accessing the fibula was made at lateral aspect of the fibula superior to the lateral malleola. After full exposure of the fractured ends, the displacement was reduced and internal fixation was achieved by plates and screws. After irrigation of the surgical wound by normal saline and full coagulation of bleeding, the wound was closed as mentioned above.

Postoperative management

Patients received prophylactic antibiotics 1 day prior to surgery. Mannitol and sodium aescinate were administered for amelioration of postoperative swelling. Before bone union was achieved, all patients were advised not to bear weight and to use the crutch for assistance in walking. Beginning from 2 days after surgery, the patients were instructed to do functional exercise on the bed. Patients were followed up for a mean duration of 3 months after surgery.

Parameters for efficacy evaluation

Operative time, skin wound healing (12 days after surgery), bone union (3 months after surgery), incidence of postoperative exposure of the hardware, incidence of infection, and functional recovery were adopted for evaluation of therapeutic efficacy. At the end of healing, therapeutic efficacy was defined as excellent, good, fair or bad according to Johner-Wruth criteria [4].

Statistical analysis

For statistical analysis, the SPSS13.0 software package (SPSS Inc., Chicago, IL) was used. All data were analyzed using analysis of variance. Non-parametric analysis was used for comparison of measurement data with heterogeneity of variance or enumeration data. $P<0.05$ was considered statistically significant.

Results

Both groups were similar in mean age, gender, injury mechanism, and location of the fracture (**Table 1**). As shown in **Table 2**, the operative time in the single-incision group was significantly shorter than that in the double-incision group ($P<0.05$). In addition, the rate of skin wound healing 12 days after surgery and the rate of bone union 3 months after surgery in the single-incision group were significantly higher than those in the double-incision group (**Tables 3**, **4**; $P<0.05$). Furthermore, the incidence of postoperative complications was sig-

Figure 2. AP X-ray radiographs and lateral X-ray radiographs of a MLTF of the left leg. A. Preoperative radiographs; B. 6 months after surgery; C. 12 months after surgery.

nificantly lower in the single-incision group than that in the double-incision group ($P<0.05$).

The length of follow-up ranged from 12 to 40 weeks, averaging 30.6 weeks. According to the function score of Johner-Wruth criteria, in the single-incision group, there were 80 patients with excellent efficacy, 18 patients with good efficacy, 7 patients with fair efficacy, and 5 patients with bad efficacy. The effective rate was 95.45%, and the excellent-good rate was 89.09%. In the double-incision group, there were 58 patients with excellent efficacy, 22 patients with good efficacy, 13 patients with fair efficacy and 9 patients with bad efficacy. The effective rate is 91.17% and the rate of excellent and good efficacy was 78.43%. There was significant difference of excellent and good rate between the single-incision group and the double-incision group (**Table 5**; **Figure 2**, $P<0.05$).

Discussion

The skin incision in MLTFs significantly affects therapeutic outcomes [3]. The skin and soft tissue in the anteromedial aspect of the tibial bone is scarce, and can be subject to necrosis and defect in trauma or surgery [5]. After proper reduction and internal fixation, the two factors that account for good efficacy are sufficient blood supply for the fractured protection of soft tissue and the subcutaneous vascular plexus [6]. Disruption of soft tissue might not only lead to hardware exposure and post-operative infection, but also increase the difficulty in subsequent flap transfer if necessary. Therefore, an optimal skin incision for MLTFs should be developed to minimize the exposure of fractured ends, disruption of soft tissues, and devascularization of the fracture fragments.

The conventional surgical approach for treatment of MLTFs employs two skin incisions. Most frequently, one incision is made on the anteromedial aspect and the other on the anterolateral aspect of the leg to expose the tibial and fibular fractures respectively [2]. This two-incision approach has the following obvious disadvantages. Firstly, the anteromedial skin incision aggravates the trauma to the skin and soft tissue on the anteromedial aspect which has already been injured by accident mechanisms [7]. Scarcity of the soft tissue, together with implanted hardware and trauma-related swelling, can make the closure of the wound extremely difficult in some patients and sometimes lead to necrosis of skin around fractured site, leading to exposure of hardware, osteomyelititis, or non-union. Secondly, the nutritional arteries of the tibia often enter cortex at the distal third of the tibia, then travels downward for 3-4 cm in the cortex before entering the medullary cavity. The fracture at the mid-to-lower segments of the tibia can damage the nutritional vessels, making the blood supply to the fractured site mainly depend on the periosteal vascular plexus, which therefore need to be left as intact as possible. However, anteromedial incision can impose additional damage to the periosteal vascular plexus, further increasing the chance of delayed union or non-union of fractures. Thirdly, the skin on the posterosuperior aspect site of the leg is the most important donor site of regional flaps, such as the distally-based sural neurovascular flap or saphenous neurovascular flap, for second-staged treatment in case of bone or hardware exposure. The double-incision approach that employs an anteromedial and an anterolateral approach can disrupt the vascular network of pedicles of the commonly-used distally-based flaps, making the resurfacing of exposed bone or hardware more difficult if necessary [8].

In previous studies, the anatomy related to MTLFs was investigated and indicated that: (1) the skin over the medial aspect of the tibia is scarce in soft tissue, making it in direct contact with the tibia, relatively weak in vascularity and impact absorption. Therefore, the fracture occurred at the medial aspect of the tibial tends to be an open one and the incision wound would often have trouble in healing, resulting in hardware exposure [9, 10]; (2) the skin incision of single-incision approach corresponds to the anterolateral intermuscular septa, which enables the surgeon to simultaneously access both the tibia and fibula. The anterolateral compartment of the lower leg contains the anterior tibial muscle, the extensor hallucis longus, the extensor digitorum longus, the deep and superficial peroneal nerves [11]. Due to the abundance of soft tissue, the most common complication following hardware implantation is the exposure of the muscular tissue [12]. Hardware exposure is rarely encountered in anterolateral aspect of the lower leg. The exposure of muscular tissue can be treated by direct closure or skin graft 10 to 14 days after the subsidence of trauma-related swelling; (3) between the middle and lower thirds of the tibia, stress concentrates, and the shape of the horizontal section of the tibia changes from triangular to quadrangular, both of which make it the most frequent site for the occurrence of fracture [13]. The shaft of the tibia is mainly supplied by a nutritional artery, which enter the cortex at the junction of the superior and middle thirds of the tibia and penetrate into the medullary cavity after traveling downward in the cortex for 3 to 4 cm. The fracture occuring at this segment frequently severs the nutritional artery and greatly weakens the vascularity, making the vascular supply to the tibia completely dependent on the vascular plexus in the periosteum. Consequently, great caution should be taken to protect the integrity of the vascular plexus in the tibial periosteum. However, the double-incision approach imposes unnecessary damage on the vascular plexus of the tibial periosteum, affecting the vascular supply to the areas surrounding the fracture; (4) The single-incision approach, compared to the double-incision approach, has the advantage of better preserving the integrity of the vascularity of the skin and the subcutaneous tissue around the fractures, which is thus beneficial for wound healing and bone union. Moreover, the skin over the medial and posterior aspects of the lower leg is not disrupted, making them an ideal donor site for harvesting the posterior tibial artery perforator-based flap or the saphenous neurocutaneous flap for coverage of the potential hardware exposure [14, 15].

For single-incision approach, the skin incision locates on the anterolateral aspect of the leg, through which a surgeon can pass through the lateral compartment of the leg to reach both the tibia and fibula. Our previous experience demonstrated that the anterolateral single-incision approach can achieve a satisfactory exposure of the tibia and fibula. Since there are adequate soft tissues in the anterior compartment, such as tibialis anterior, extensor hallucis longus, and extensor digitorum longus, open reduction and internal fixation through the anterolateral approach can reduce the chance of occurrence of bone and hardware exposure [16]. Moreover, since the incision is made at the anteromedial aspect of the leg in the single-incision approach, no further damage is inflicted on the vascular plexuses, which is beneficial for fracture union. Finally, based on the perforators of the posterior tibial artery, the saphenous neurovascular flap can be safely harvested for coverage of postoperative bone and hardware exposure [17]. In the present study, patients of the single-incision group, there were a total of 14 patients with postoperative bone or hardware exposure, among which 6 patients received coverage using flaps based on perforators of the posterior tibial artery, 4 patients using sural myocutaneous flaps, 2 patients using distally based saphenous neurovascular flaps, and 2 patients using sural neurovascular flaps. All flaps survived uneventfully. The single-incision approach also possesses advantages of being shorter in operative time, less in intraoperative bleeding and better in bone union.

Conclusion

In the present study, the single-incision approach was proved to be a safe and optimal choice for treating MLTFs. Compared to double-incision approach, this technique holds the potential of reducing tissue trauma, preserving the periosteal vascular integrity, shortening operative time, less intra-operative blood loss, and better wound healing and bone union post-operatively. However, concerning the small number of patients involved in the present study, future investigations remains to be developed to establish the safety and effectiveness of single-incision approach for treating MLTFs in the long term.

Disclosure of conflict of interest

None.

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