Case Report

Application of transverse tibial bone transport and microcirculation reconstruction in the treatment of diabetic foot ulcer: a case report

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Abstract: Diabetic foot ulcer (DFU) is a common complication in the advanced stages of diabetes mellitus. DFU in these individuals cannot heal properly over time due to microcirculatory changes that hinder and stagnate the healing process. There is a wide range of therapeutic strategies for DFU, but only minimal efficacy has been found in limited published studies. Transverse tibial bone transport (TTBT) is a new strategy for DFU, which based on Ilizarov technology. We present a case of a 45-year-old female with longstanding type 2 diabetes complicated with slowly expanding ulceration to her right foot. According to the symptoms, signs, and medical history, she was diagnosed as DFU with osteomyelitis. After sufficient preoperative preparation, including tight blood glucose control, wound dressing, and anti-infection therapy, the ulcer was treated with Ilizarov TTBT. Under these interventions, the ulcer gradually improved. The patient's foot ulcer was completely healed seven months after surgery, and foot function was well preserved. No complications were observed during the follow-up. For patients with refractory DFU, TTBT should be considered a promising treatment option for maintaining the foot's shape and function. The present study's findings indicate that further studies should focus on the mechanism of microcirculation reconstruction for the treatment of DFU.

Keywords: Diabetic foot ulcer (DFU); transverse tibial bone transport (TTBT); microcirculation; case report

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Introduction

Diabetic foot ulcer (DFU) is one of the most serious complications of diabetes mellitus (1). In diabetes with concomitant peripheral arterial disease or poor blood sugar control, localized infection, peripheral neuropathy or foot deformities, foot ischemia or neuropathy are likely to occur, eventually resulting in foot ulcers, dysfunction, and paresthesia (1,2). In some cases, patients with severe diabetes may even develop foot osteomyelitis or require lower limb amputation (3).

Many therapeutic strategies, such as topical wound oxygen therapy, shock wave, and collagen dressing, have been used to treat DFU, but their effectiveness is not significant. Transverse tibial bone transport (TTBT) is a new treatment for DFU based on Ilizarov technology. The Ilizarov technique, a biological theory put forward

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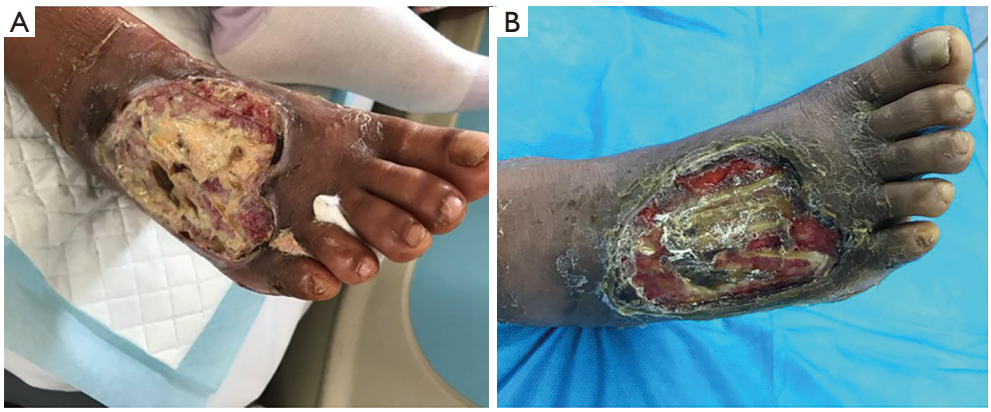

Figure 1 Changes in the ulceration at admission and at 2 weeks after admission. (A) On admission, there was a lot of exudation and pus in the ulcer. (B) Two weeks after admission, the pus in the ulcer had decreased.

Table 1 Patient characteristic

Gender	Age (years)	BMI (kg/m^2)	Fasting blood sugar (mmol/L)	Basic disease	Complication	Concomitant medications	Blood sugar control before admission
Female	45	19.4	13.4–16.8	Type 2 diabetes; hypertension	Osteomyelitis; foot ulcer	Metformin; Acarbose	Poor

by Professor Ilizarov (4), is a transverse distraction of the tibial osteotomy stump with an adjustable external fixator to provide continuous tension-stress to local bone tissue and soft tissue, which could stimulate the new growth of bone and adherent muscle fiber, vascular cell, and fascia. It has been reported that, under the guidance of the tension-stress rules of Ilizarov, TTBT can reconstruct blood circulation, and stimulate tissue regeneration and active growth by continuous tibia traction. The blood supply of the bone marrow cavity in the tibia is rich, quickly forming a microvascular system. In the present paper, we report a female with DFU treated by TTBT according to the Ilizarov technique. We found a few reported cases on TTBT in the treatment of DFU in our literature search. We present the following case in accordance with the CARE reporting checklist (available at http://dx.doi.org/10.21037/apm-20-2053).

Case presentation

In 2018, a 45-year-old woman with type 2 diabetes for 16 years began to develop pea-sized nodules on the dorsum of her right foot, with local redness and itching. After the nodule was scratched, a yellowish fluid was observed. The skin of the foot's dorsum then began to break, and the skin damage gradually increased, accompanied by pus. Physical examination showed that the skin of the dorsum of the right foot was ulcerated, and the tendon and periosteum were exposed, with a large amount of yellow and white foul-smelling pus and obvious redness and swelling around the defective skin (*Figure 1A*). The patient's superficial sensation decreased significantly, and there was an obvious obstacle to the flexion and extension of her right toes.

After admission, the following laboratory results were obtained: white blood cell 6.76×10^9/L, the absolute value of neutrophils 3.77×10^9/L, hemoglobin 112 g/L, C-reactive protein 15.20 mg/L, glycated haemoglobin 86 mmol/mol (10.5%), and erythrocyte sedimentation rate 95 mm/h. Bacterial culture was negative. Imaging findings showed irregular bone morphology and osteomyelitis at the distal edge of the 5th toe of the right foot. According to clinical manifestations and her long-term history of diabetes, the patient was diagnosed as DFU with toe osteomyelitis (*Table 1*). After 2 weeks of tight blood control, wound dressing and anti-infection therapy (*Figure 1B*), the ulcer was treated with Ilizarov TTBT (*Table 2*).

Under general anesthesia, with the patient in the supine position, 2 external fixation half-pins of suitable length were

Table 2 Ulcer management during the patient's treatment

	Measures	Usage and dosage
Blood sugar control	Insulin aspart; insulin detemir	Before breakfast (18 U), lunch (16 U), and dinner (18 U), subcutaneous injection, ter in die; bedtime (20 U), subcutaneous injection, quaque nocte
Wound management	Dressing with insulin-soaked gauze	External application, quaque 12 hour
Anti-infection therapy	Cefoxitin sodium	2 g, intravenous drip, bis in die

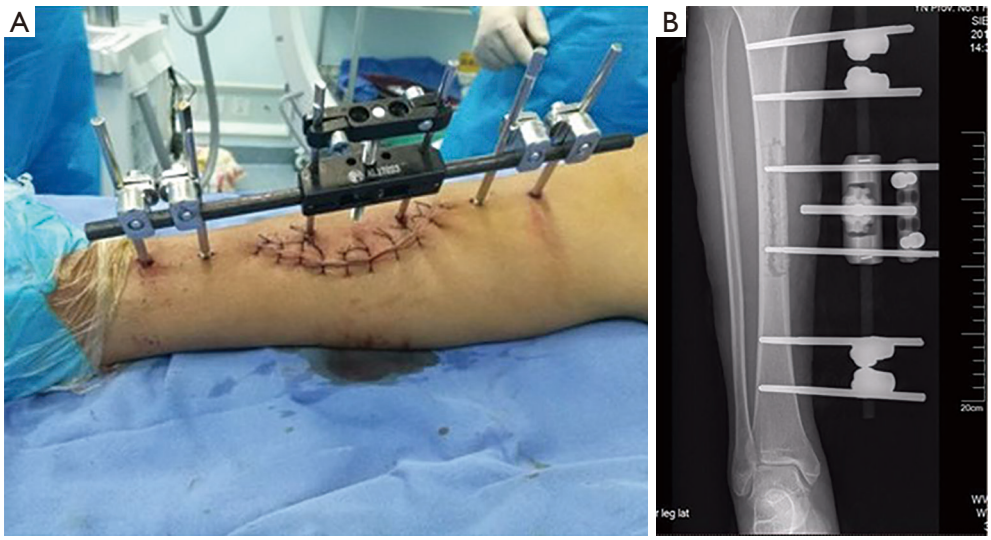

Figure 2 Transverse tibial bone transport was performed on the patient. (A) External fixator was fixed to the medial side of the tibia intraoperatively. (B) Postoperative X-ray image of the right tibia at the anteroposterior position.

placed on the medial 4 cm above the ankle joint along the right tibial axis; the other 2 fixation half-pins were placed on the medial 4 cm below the tibial tubercle. A 15-cm anteromedial curved incision was made in the middle and lower tibia. After the separation of the subcutaneous tissue, a 7 cm × 4 cm osteotomy window was created at the incision. According to the planned osteotomy range, the bone cortex was cut with a swing saw to form a movable bone flap. Two half-pins in the center of the external fixator were inserted into the upper and lower parts of the bone flap to laterally move the osteotomy. After the angle was adjusted properly under the supervision of the C-arm, the external fixing bracket with 2 lateral tractors was installed on the 4 external fixation pins, and the tractors were fixed to the traction pins (*Figure 2A*). An X-ray showed that the screw penetrated 2 layers of bone cortex, and the position of the external fixator was satisfactory (*Figure 2B*). The operation went well, and there were no intraoperative complications. Purulent secretions and necrotic tissue in the foot ulcer were properly cleaned and covered with sterile dressings.

After the operation, the dressing was changed regularly, the anti-infective drugs were used regularly, blood sugar was controlled strictly, and the patient's foot function was strengthened through exercises. After these interventions, the bone transport operation was started on the 7th postoperative day. The osteotomy was pulled laterally 1 mm on every day and stopped after 14 days, and then pushed back for 14 days. The above process was repeated 3 times, and the external fixator, which was used for 7 months in total, was removed after the fracture healed. The patient's symptoms alleviated, and the ulcer in the right foot healed gradually after the operation. The ulcer began to shrink, and the dorsal foot skin temperature improved significantly from the 1st week to the 3rd week, postoperatively (*Figure 3A,B,C*). After discharge, we arranged a 24-month follow-up (*Table 3*). The ulcer in the patient's right foot improved, and the redness and swelling subsided significantly from the 12th week to the 16th week,

Figure 3 Changes in the ulceration from the 1st to the 28th week, postoperatively. (A) At 1 week postoperatively, the effusion had significantly decreased. (B) At 2 weeks postoperatively, granulation tissue had appeared. (C) At 3 weeks postoperatively, the ulcer area had significantly reduced. (D) At 12 weeks postoperatively, cutaneous sensation had improved significantly. (E) At 14 weeks postoperatively, the depth of the ulcer was significantly shallow. (F) At 16 weeks postoperatively, the ulcer had scabbed over. (G) At 20 weeks postoperatively, the scab was replaced by new skin tissue. (H) At 24 weeks postoperatively, the scab came off. (I) At 28 weeks postoperatively, the ulcer had completely healed.

postoperatively (*Figure 3D,E,F*). From the 20th week to the 28th week, postoperatively, the foot ulcer had healed completely, and foot function had recovery (*Figure 3G,H,I*). No complications were reported during the follow-up.

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). Written informed consent was obtained from the patient for publication of this case report and any accompanying images.

Discussion

With the increasing number of people with diabetes, foot ulcers are increasingly common. It places a considerable burden on people with diabetes and society in general and increases the morbidity, burden of health care, and mortality (1,5). People with DFU have a 2.5 times higher risk of death within 5 years than those without (6). It is estimated that the incidence of ulcers, infections, and

Table 3 Wound baseline characteristics of the patient postoperatively

Period	Ulcer area (cm^2)	Depth (mm)	Wagner classification	Cutaneous sensation	Skin temperature	Pus
Admission	80	22	3	Poor	Low	Yes
1st Week	67.5	20	3	Poor	Low	Yes
2nd Week	57	18	2	Poor	High	Yes
3rd Week	52	17	2	Poor	High	Yes
12th Week	35	14	2	Normal	High	Yes
14th Week	25	11	2	Normal	High	Yes
16th Week	12	9	1	Normal	Normal	No
20th Week	8.8	6	1	Normal	Normal	No
24th Week	6	3	1	Normal	Normal	No
28th Week	0	0	0	Normal	Normal	No

amputations among people with diabetes is 68%, 36%, and 6%, respectively (7). Our patient was diagnosed as DFU with osteomyelitis of the phalangeal bone of the right foot in the present case. Laboratory results showed that the erythrocyte sedimentation rate and C-reactive protein were significantly increased, but the bacterial culture was negative. As the most common pathogen of diabetic foot is *Staphylococcus aureus*, we used pentahydrate cefazolin to conduct prophylactic antibacterial treatment on the patient during hospitalization (5,8).

TTBT is a novel method for the treatment of DFU. At present, there are few reports on its mechanism. The distraction histogenesis principle is that a certain tension will be generated when the biological tissue is pulled slowly, stimulating neovascularization and increasing perfusion to the bone and surrounding soft tissues. TTBT can upregulate the expression of vascular endothelial growth factors, which can stimulate collagenase production, effectively inhibiting the synthesis of hydroxyproline and promoting vascular regeneration (9,10). Zeng *et al*. used computed tomography to observe blood perfusion after TTBT and found that TTBT could increase plantar tissue perfusion, which may be related to increased functional capillaries opening (11). In our study, the foot ulcer healed completely over time, and lower limb temperature and pain improved significantly. This suggests that lower limb revascularization was successful. Chen *et al*. reported that TTBT can effectively reduce amputation and recurrence rates and that the complications of TTBT are minimal (12). Using a transverse distraction model of the canine tibia, Matsuyama *et al*. found that the average vascular volume ratio in the stretch area was more than 3 times that of the intact contralateral tibia (13). Therefore, TTBT has the advantages of less trauma, lower cost, faster recovery after an operation, lower amputation rate, effectively relieving pain, improving skin tone, and reducing local swelling.

In addition to surgery, we also taught the patient about proper foot care, such as having regular foot check-ups, controlling her blood sugar, avoiding infections and injuries, wearing comfortable footwear of the right size, and avoiding long-time standing, which are effective interventions to promote foot ulcer healing (1,14). Based on her age, physical condition, the degree of DFU, and the severity of complications, we also provided the patient with individualized education, which could effectively reduce anxiety, enhance adherence to therapy, improve wound healing, and shorten the length of hospital stay.

However, the treatment of DFU is complicated. The curative effect of TTBT on diabetic foot is closely related to the cooperative treatment of vascular surgery, endocrinology, and nursing (15). The patient's foot had to be fixed to an external fixator for at least six months, so good compliance is also required. Some studies have found that the healing of ulcers is affected by factors, such as the site of osteotomy, method, waiting time, speed of distraction, the blood supply of surrounding tissue, and soft tissue condition (16); therefore, proper management of people with DFU by medical staff is particularly important.

Our study and operation have some limitations. We only researched 1 patient; therefore, the advantages and disadvantages of TTBT are limited to our patient. The effectiveness of TTBT in other lower extremity

microvascular diseases, such as thromboangiitis obliterans and arteriosclerotic obliteration, is uncertain. Besides, patients with TTBT need to spend long periods to use external fixation, making them inconvenient in their treatment. More population-based trials are needed to demonstrate the safety and effectiveness of the procedure.

In conclusion, TTBT can promote vascular regeneration and tissue repair of the foot and accelerate ulcer healing, and appears to be an effective measure for the treatment of DFU.

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Footnote

Reporting Checklist: The authors have completed the CARE reporting checklist. Available at http://dx.doi.org/10.21037/apm-20-2053

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at http://dx.doi.org/10.21037/apm-20-2053). 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). Written informed consent was obtained from the patient for publication of this case report and any accompanying images.

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