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Research Article

Repair of Infected Femoral Bone Defect with Free Fibula Transplantation

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Abstract

Objective

To explore the clinical application and effect of free fibula transplantation in the treatment of femoral infectious bone defect.

Methods

From April 2008 to April 2013, 9 patients that had infectious bone defect in femur underwent repair with free vascularized fibular graft, the bacterier cultivation of sinus tract excretion in preoperation and focal zone in operation have proved the infection including 7 males and 2 females with an average age of 34 years (24-43). The length of bone defect were 7.5 cm on average. The bone defect was repaired with free vascularized fibular graft on one stage in 6 cases and two stages in 3 cases after the cure of infection. Six patients underwent folded and three patients underwent single vascularised fibula graft transfer. The skin island flaps were used as a postoperative predictor of vascularized fibula graft viability in 6 cases. The transfer fibular were fixed with plate in 6 cases, external fixor in 3 cases. Time to union was recorded through evaluation of plain radiographs. The Enneking score system was applied to evaluate the lower extremity function.

Results

The vascularized fibular survived and bony fusion was achieved in all patients. All cases were followed up. A mean follow-up was 24.5 months (12-39). The average length of the transfer fibula was 14.5±3.2cm. The average time for bone union at allograft-host junction was 5.5±1.2 months. Of the 9 cases, the mean scores was 24(their scores ranged from 20 to 27) at final follow-up. The functions of supplied regions were not found malfunctional, no recurrence of infection occurred. There were no stress fracture in inlay fibula.

Conclusions

Free vascularized fibular graft will benefit to control the infection in femur, have high bone union rate, and was an optimal choice.

Introduction

Femoral shaft fractures are common in clinic, and severe trauma often leads to collapse, comminuted fracture and even open fracture of limb soft tissues. Incomplete debridement of open fractures or improper selection of internal fixation materials and various iatrogenic factors in early treatment of closed fractures can lead to infection [1]. If infection persists, sequestrum can be discharged intermittently through sinus tract or bone defect can be left after repeated debridement. Infectious bone defect is a great challenge for trauma orthopedic surgeons. Bone defect and bone infection often exist at the same time.

Infected bone defects are often longer than 6 cm in length after repeated treatment, which is called long bone defect. For femur, a contraction of 2cm will cause lameness. Therefore, infected bone defect of femur should not only eliminate infection but also restore limb length [2]. Because of its tubular bone structure and hard cortex, fibula has always been an ideal choice for repairing tubular bone defects of limbs. However, there are the following problems in repairing femoral bone defect with fibula transplantation: the position of femur is deep, and the branches of femoral artery in the distal thigh are thin and unstable, which brings inconvenience to microvascular anastomosis; Wood *et al.* [3] reported that the average area of middle femur in adults was 384 [2] mm and that of fibula was 102mm [2], so the incidence of stress fracture after repairing femoral bone defect with a single fibula was high. The thick soft tissue of the middle and upper segment of femur makes it difficult to suture and fix the fibula carrying flap when it is used to monitor blood flow and skin island. In view of the above reasons, in recent years, unilateral or annular external fixator is increasingly used to treat femoral bone defects. However, the treatment period of bone transfer is long and requires special complicated devices, which affects daily life. When soft tissue of thigh is thick, pin holes of external fixation are easy to be infected [4]. The application of external femoral fixator will cause knee joint disorder of flexion and extension. Proximal femur bears great stress, which may lead to poor force line of limbs during sliding.

From April, 2008 to April, 2013, 9 cases of femoral infectious bone defects were repaired with free fibula transplantation in the first or second stage according to the infection. Some bone defects were repaired with single fibula transplantation, and those with femoral segmental defects were repaired with double fibula transplantation. During the operation, fibula was fixed with steel plate or external fixator to ensure the accuracy of femoral force line. The alignment of the transplanted fibula and femur is satisfactory. Peroneal perforator flap was carried to monitor the skin island during fibula resection. The satisfactory effect was reported as follows.

Materials and Methods

General Information

From April, 2008 to April, 2013, 9 cases of femoral infected bone defect underwent free fibula transplantation. Preoperative sinus secretion and bacterial culture at the focus during operation all confirmed the infection, including 3 cases of Escherichia coli bacterial infection, 4 cases of drug-resistant Staphylococcus aureus infection and 2 cases of mixed infection. 9 patients including 7 males and 2 females with an average age of 34 years (24~43). Original injuries: 5 cases of car accidents, 2 cases of crushing injuries, 2 cases of falling injuries. 9 cases of femoral bone defect had sinus formation. Among them, 6 cases of sinus tract had self-healing when they came to hospital, and 3 cases of sinus tract still had secretions flowing out. Bone defect sites: 3 cases in the subtrochanteric region of femur (near the femoral isthmus), 5 cases in the middle of femur, and 1 case in the supracondylar region of femur. (Table1)

Table 1: *Clinical characteristics of total 9 patients.*

Patient characteristic	**No.**
Median age (range), yrs	34(24-43)
Sex, n (%)	
Male	7(78%)
Female	2(22%)
The original injuries	
Traffic accident	5(56%)
Crushing	2(22%)
Falling	2(22%)
Sinus formation	
Self-healing	6(67%)
Still had secretions	3(33%)
Bone defect sites	
Subtrochanteric region of femur	3(33%)
Middle of femur	5(56%)
Supracondylar region of femur	1(11%)

Infections	
Escherichia coli bacterial	3(33%)
Drug-resistant Staphylococcus aureus	4(45%)
Mixed	2(22%)

The Operation Method

The First Stage of Operation

The group of patients were examined and found that the preoperative sinus tract was closed, local inflammatory reaction was not serious, and preoperative blood routine examination, sedimentation rate and C-reactive protein examination were normal. Preoperative routine X-ray and CT examination were performed to understand the location of osteomyelitis sequestrum and abscess cavity. Arterial angiography of both lower limbs was performed to understand the vascular condition of the injured limb and the type of peroneal artery of the contralateral limb.

Lesions Cleared

Debridement should be carried out from shallow to deep. Skin incision should facilitate the complete removal of the original fistula, separation of blood vessels and fixation of fibula transplantation. If necessary, double incisions can be used. The medial femoral sinus in 3 cases were formed. The medial incision was used to remove sinus and lesions. Anterolateral incision was used to dissect blood vessels and fix fibula. Large pieces of sequestrum and dead cavities were removed, and whole sections of infected bone were resected when necessary until punctured blood oozed from the upper and lower bone ends of the defect. During the operation, attempt should be made to keep the vascularized bone connecting with the surrounding soft tissue to increase the local strength. If there was external fixation, it should be removed for thorough debridement of medullary cavity, and if there was internal fixation, it should be removed either. Three inflammatory tissues around the lesion were taken for bacterial culture and drug sensitivity test. After extensive washing, the length of the bone defect was measured after a large number of rinses, and electrocoagulation was used to complete hemostasis.

Femoral Fixation

In this group of 3 patients, the medial cortex of femur was connected and only the lateral defect was found after debridement. External fixation stent was used to fix the upper and lower bone ends during the operation to increase the stability of the transplanted fibula. The fracture of 6 cases treated with plate fixation was reduced by traction to maintain the accuracy of femoral bone force line. The thick line of the posterior femur could be touched as a reduction mark, and the length of the femur was restored. The anatomical plate of the distal end of femur was inverted or the anatomical plate of the proximal end of femur was fixed. Intraoperative fluoroscopy was repeated to ensure the accuracy of the lower limb force line.

Vascular Anatomy of the Recipient Area

Dissection was made through anatomical femoral muscles and lateral rectus, looking for a descending branch and track upward the descending, horizontal and ascending branches of the lateral femoral circumflex artery. Blood vessels were chosen based on bone defect site. Descending branch could be used as blood supply artery for upper segment defects. The great saphenous vein can be dissected to the recipient area. The inferior segment defect was anastomosed with femoral artery end-to-side.

Fibula Transplantation

The fibula was grafted on the healthy side and cut along the posterior edge of the fibula to find the perforating branch of the peroneal artery. It was found that the perforating branch was dissected posteriorly to the deep surface, so as to prevent injury of the tibial nerve and the peroneal vein in the process of dissecting the peroneal vessels. Proximal dissociation prevents accidental injury of the common peroneal nerve branch. The fibula was cut according to the measured length of the bone defect. After the fibula was cut with a wire saw, the flap was cut and used to monitor the blood supply of the fibula. The flap should not be too large. When the fibula was double folded, the pedicle was removed laterally at the fracture site to prevent the pedicle from folding at an acute Angle with the fibula. The two fibulas were fixed together with cortical screws and the fibula flap was grafted into the bone defect. In this case, the flap was slightly longer than the length of the defect and the recipient bone could be slotted to insert the fibula flap into the bone defect. Fluoroscopy ensured that the fibula axis was consistent with the limb force line to prevent the fibula from tilting. Finally, the flap was sutured and fixed.

Staged Operation

If the infection was severe, sinus exudation was excessive, and local inflammatory reaction was obvious, with abnormal erythrocyte sedimentation rate and C-reactive protein by the preoperative examination, the patient was suitable for staged operation. The first-stage operation was to remove the lesions (the same-stage operation). According to the length of the bone defect, the bone cement (antibiotic concentration 10%) compounded with norvancomycin was molded in vitro to form the shape of the defect bone. When the cement does not stick to the hands, it was implanted into the body to the extent that the bone cement blocks were embedded in the proximal and distal medullary cavities. After the cement was solidified, the bone cement fragments were removed, and the external fixation bracket was installed and connected. Fluoroscopy was made to ensure that the length of the limb was restored and the force line was good. After the surgery, the patient practiced the range of motion of the joint and walked with weight on the ground with both crutches.

The erythrocyte sedimentation rate and C-reactive protein were all within the normal range. After admission, the external fixation bracket was removed and the operation was performed after the pinhole healing of the external fixation bracket. A locking steel plate was inserted to fix the upper and lower ends of the bone defect according to the location of the bone defect. The bone cement placeholders were removed, and the membrane structure outside the bone cement placeholders was retained as far as possible. The size of the bone defect was measured, and the bone cement fragments in the wound surface should be completely removed. Fluoroscopy ensures recovery of limb length and force line. The fibula was grafted according to the one-stage method, and the grafted fibula was located in the cement membrane.

Post-Operative Treatment

After operation, 7 days of anti-inflammatory, anticoagulation and antispasmodic treatment were needed. In this group of 6 patients with skin flap, the skin flap should be fully exposed after operation, and the skin flap color and capillary filling reaction should be closely observed. Special attention should be paid to the observation of the exposed skin flap periphery (bluish purple and spotted at the periphery of the skin flap in early venous crisis). Postoperative dressing change was strengthened to keep the dressing dry. X-ray reexamination was conducted 10 days, 1 month, 2 months, 3 months, 6 months, 9 months and 12 months after the operation to understand the healing of the transplanted fibula and the bone in the recipient area. After the stitches were removed, active functional exercise of knee and hip joint was performed to prevent joint adhesion. Six weeks after the operation, when the X-ray showed signs of healing of the transplanted fibula and the femur in the affected area, the patients could walk with weight bearing under the ground with two crutches, and further increase the weight bearing according to the progress of X-ray bone healing. In this group, the external fixation was removed 4 months after operation and the support was protected for 4 weeks on average.

Postoperative Follow-up and Curative Effect Evaluation

The patients were followed up once a month within 3 months, and after that once every 3 months. According to the X-ray bone healing, the patients were instructed to walk with weight, and the blood routine, erythrocyte sedimentation rate and C-reactive protein were rechecked to find out whether the infection had recurred. Enneking score [5] was used to comprehensively score the function of the affected limb after operation in six items: pain, limb function, emotional acceptance, support, walking ability and gait. Out of 30 points, the highest 5 points for each item indicate fully recovered. The lowest 0 point represents serious obstacles, 24 points excellent and 21 points good.

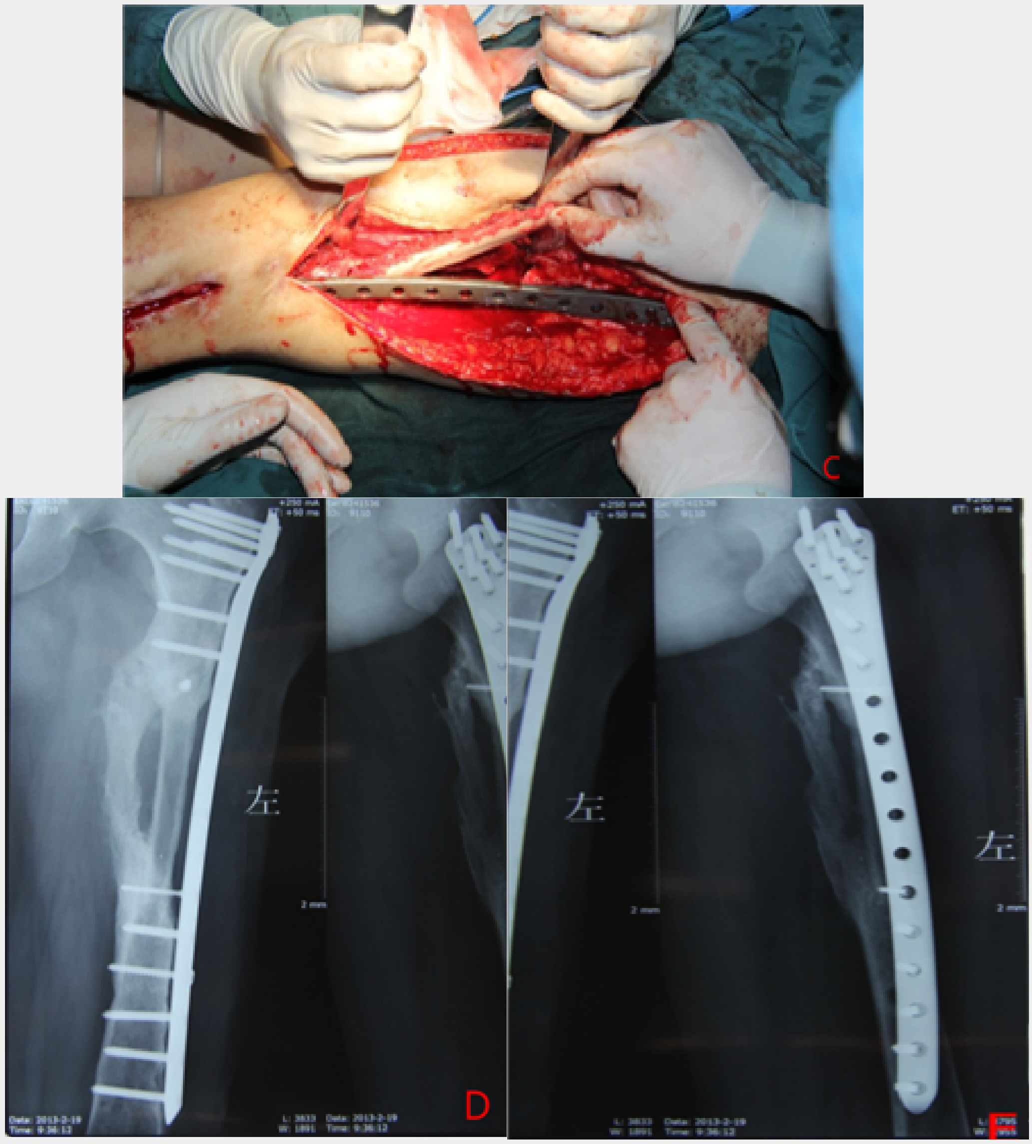

Figure 1: *The patient was a 26-year-old male. After debridement of left femoral shaft osteomyelitis, the antibiotic cement placeholder (A) was placed due to severe infection. Three months after operation, the placeholder (B) was taken out, and the opposite fibula was transplanted. First, the upper and lower ends of the bone defect were fixed to maintain the force line of the lower limbs, and then the fibula was inserted and fixed with the femur (C). Six months after operation, the transplanted fibula and femur healed well, and the internal fixation did not loosen or break. The function of affected limb was satisfactory (D, E).*


L
A
B
C
D
E
F

***Figure 2:** The patient was a 32-year-old male, suffered from an open fracture of the left subtrochanteric femur caused by crush injury. Emergency debridement, reduction of fracture and PFNA fixation (A and B) were performed. After the operation, the wound was intermittently drained of pus and sinus was formed for 3 months (C and D). Segmental defect of the subtrochanteric region was found during the operation (E). The free fibula with peroneal artery perforator flap was cut out for 14cm (F). The fibula was implanted and fixed with the femur to maintain satisfactory limb force line. Five months after operation, the fibula and femur healed (J, H), and the blood supply of the flap was good (I).*

Results

Treatment Result of Infection

The patients were followed up for 12~39 months, with an average of 24.5 months. The wounds of 9 patients after fibular transplantation were all healed in one stage, and there was no recurrence of infection. Among the 3 patients treated with external fixation, 1 patient showed redness and abnormal secretion of nail holes (which had nothing to do with the original infection after bacterial culture). After intensive dressing change and smooth drainage, the patient was cured with noraml blood routine, erythrocyte sedimentation rate and C-reactive protein after one month. Only one patient out of 9 had a thin exudate at the distal nail hole of the steel plate 6 months after operation. With negative bacterial culture, normal erythrocyte sedimentation rate and C-reactive protein, the patient was self-healing after removing the steel plate. This study was approved by Ethics Committee)

Bone Healing Result

The average healing time of transplanted bone and femur was 5-7 months, with an average of 5.5 months. Flaps of the six patients survived without vascular crisis during operation, which proved that the transplanted fibula survived. Three patients without flaps showed callus formation at the junction of the transplanted fibula and femur 1 month after operation, and no sign of fibula absorption was found in postoperative follow-up. There was no second bone grafting in this group and no fibular stress fracture occurred after operation.

Functional Result

Enneking lower limb function scores ranged from 20 - 28 points, with an average of 24 points. Four patients had knee joint dysfunction before operation, among which 2 patients had knee joint motion range of 0°~ 110°after functional exercise, and 2 patients received knee joint adhesion release, and the postoperative function recovery was satisfactory. One patient had preoperative hip flexion disorder of 0°~ 45°, and the range of hip motion was 0°~ 100°by functional exercise after fibula transplantation. The donor site wounds were sutured directly and healed in one stage without dysfunction (Table 2).

Table 2: *Results*

Fellow-up average of 24.5 months(12-39 months)
None of 9 patients were infected
All patients were healing well
The average healing time of transplanted bone and femur was 5-7 months
Enneking lower limb function score with an average of 24 points (20-28 points)

Discussion

It is a tough job to treat infectious bone defects and osteomyelitis of femur aroused by various reasons. Palliative debridement cannot effectively cure the infection. Thorough debridement of infected lesions will leave a wider range of bone defects and make treatment more difficult, which puts orthopaedic trauma surgeons in a dilemma [6]. However, bone defect repair and reconstruction based on thorough debridement is still the standard treatment method for infectious bone defects. There are many treatment methods for long bone defects larger than 6cm. Bone transfer technology based on Ilizarov's tensile stress rule and micro-repair technology represented by free fibulatransplantation are the most commonly used methods for treating large bone defects [7]. As the largest weight-bearing long tubular bone in human body, the repair of femoral bone defect requires not only high bone healing rate, but also high mechanical strength and good force line of lower limbs after repair. All 9 patients in this group had bone defects larger than 6 cm. In adults, the length of unilateral fibula is 30cm [8]. In this group, a single fibula graft was used for some bone defects. Double-folded fibula transplantation was used to repair the segmental defect of femoral bone, and the accuracy of femoral force line was ensured during the operation. Due to the rich soft tissue of the thigh, unlike the tibia, the infectious bone defect of the femur is not associated with soft tissue defect, but the long-term drainage of pus in the sinus can also cause local scar formation. In this study, 6 of the 9 patients carried peroneal perforator flap, and 2 of the 3 patients without flap gave up the flap because no reliable peroneal perforator was found in the anatomy, and 1 patient injured the perforator during the cutting process. The flap can not only monitor the blood supply of the transplanted fibula, but also improve the soft tissue coverage of the bone defect and promote bone healing [9].

The author suggests that free fibula graft can repair femoral bone defects especially for segmental bone defects of 4-10 cm in the middle and upper femur. Conventional bone grafting is difficult to succeed in 4-10cm femur bone defect, and the mechanical strength of single fibula graft is poor and the incidence of postoperative stress fracture is high. Therefore, repair with double fibula can meet the mechanical strength requirements. The length of unilateral free fibula double fold is not enough for the femoral bone defect of more than 10 cm. It has been reported that bilateral fibula was cut and transplanted to repair the large femoral bone defect. However, the surgical trauma is large, and a vascular anastomosis is added to prolong the operation time. The bone defects in this group were 4-10 cm in length, with an average of 7.5 cm. Double-folding with a single fibula graft on the healthy side can meet the needs. When double-folding fibula, periosteum should be peeled off to both sides at the truncation point to increase the flexibility of soft tissue. After this improvement, fibula can be directly truncated without cutting off a 2 cm fibula [10]. In 3 cases of this group, the medial cortical bone of about 1/3 circumference was connected and healed. In this case, the repair of partial femoral bone defect with a single fibula can meet the mechanical strength. There are more femoral artery branches in the middle and upper segment of the thigh, and the descending branch of the lateral femoral artery can be easily dissected between the rectus femoris muscle and the vastus lateralis muscle, matching the diameter of the peroneal artery and facilitating vascular anastomosis. The femoral artery branches at the distal end of the thigh are few and the blood vessels move towards the medial side. When repairing the bone defect at the distal end of the femur, the peroneal artery even needs end-to-side anastomosis of the femoral artery, which increases the difficulty of the operation. Sometimes the fibula transplantation and vascular anastomosis cannot be completed in the same incision, so another incision is required. The diameter of the peroneal vein is usually large, so finding suitable vein anastomosis in the recipient area is often the key to the success of the operation [11]. Traditional fibula bone flap is characterized by close connection between fibula and flap, and leg soft tissue is thick, thus fibular flap transplantation is easy to invaginate, and difficult to suture. We adopt chimeric peroneal artery perforators flap free fibula transplantation because peroneal artery perforators is long, and combination of bone flap and flap with osteoporosis increased flexibility. The flap can be used to monitor the skin and improve local soft tissue coverage.

The primary or secondary repair mainly depends on the infection. The traditional idea is that the bone defect can be repaired only after the infection is cured [12]. The primary repair effect of 6 cases of infected bone defect in this group is satisfactory, which proves that the primary repair of bone defect based on thorough debridement is feasible. This makes higher requirements for debridement. Debridement should be thoroughly expose extensively, especially for the femoral medial and the back which is not easy to achieve thorough debridement. If necessary, bone infection and infection of the tissue were removed. It is worth noting that leg soft tissue possesses stronger anti-infection ability, the actual infection is often heavier than the performance [13], thus the second phase is also recommended. Inspired by artificial joint surgery [14], our self-made antibiotic bone cement space-occupying device has also achieved satisfactory results in the treatment of infectious bone defects. The release of antibiotics in bone cement is completed by the dispersion of concentration gradient, which increases the concentration of antibiotics in osteomyelitis site and increases the cure rate of infection. After the application of local drug delivery system, the local administration system provides a stable drug concentration and avoids the side effects of systemic administration. Implantation of the space-occupying device will not change the characteristics of antibiotics [15]. Furthermore, after the antibiotic bone cement is applied, a biofilm will be formed around the antibiotic bone cement, which has osteogenesis [16]. To a certain extent, it is beneficial to the healing of fibula and recipient area in the later period. The space holder can also provide space for the second fibular transplantation.

The reported incidence of stress fracture after fibula transplantation is 9%-40% [17]. Thus, delayed weight-bearing time and limited weight-bearing will affect the function of the affected limb. The mechanism of "femoral ossification" of the so-called fibula graft is unclear [18]. Some studies have shown that when two fibulas are transplanted to repair femoral bone defects, the thickening trend of the load-bearing fibula located in the center of the medullary cavity is more obvious. Therefore, it can be concluded that stress stimulation can make the transplanted fibula remodeled and thickened to meet the needs of function. According to K. Muramatsu's report [19], 3 cases (3/24) of graft fibula fractures were related to poor graft fibula force line. It was emphasized that the risk of angulation fracture of the graft fibula greater than 15 degrees would be greatly increased. Therefore, it is very important to ensure the accuracy of the graft fibula force line. There was no stress fracture in 9 cases in this group. Plate fixation was used for segmental defect to ensure accurate force line. External fixation was used for partial bone connection to increase stability, and external fixation could be removed early after fibula healing. Compared with external fixation, internal fixation has obvious advantages in controlling limb force line, which is worth advocating [20].

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