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Research Article

Single and Double Level Bone Transport in the Treatment of Patients with Femoral Defect Caused by Chronic Osteomyelitis

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Abstract

Objective: To investigate the efficacy and complications of single and double level bone transport in the treatment of patients with femoral defect caused by chronic osteomyelitis.

Methods: The clinical data of 42 patients with femoral defect caused by chronic osteomyelitis treated in our hospital from January 2014 to June 2018 were analyzed retrospectively. Demographic data include sex, age, injury mechanism, postoperative defect size, transport type (single or double level), time of mineralization in distracted region, external fixator index (EFI), knee joint HSS score, ASAMI score and postoperative complications.

Results: A total of 35 cases were followed up successfully, including 28 males and 7 females, 16 cases in single level and 19 cases in double level bone transport. The average follow up time was 44.77 ± 14.72 months, the average age was 30.89 ± 10.62 years, the average postoperative defect size was 9.94 ± 3.97 cm, the average external fixation index was 1.86 ± 0.55/cm. According to ASAMI scoring system, bony results was excellent in 21, good in 10 cases, fair in 3 cases and poor in 1 case, and the functional score was excellent in 0 cases, good in 13 cases, fair in 18 cases and poor in 4 case. The most common complications were pin tract infection (n=25), delayed union (n=6) and axial deviation (n=4). There were significant differences in bone lengthening index, mineralization index and EFI between single level and double level bone transport.

Conclusion: Femoral defect caused by chronic osteomyelitis can be treated effectively using single and double level bone transport technique. Double level bone transport can significantly shorten the external fixator time, and there is no significant difference in the incidence of complications between single and double level bone transport.

Keywords: Bone transport; Chronic osteomyelitis; External fixator; Femoral defect Bone transport; Chronic osteomyelitis; External fixator; Femoral defect

Introduction

The treatment of chronic osteomyelitis of the femur is a major challenge for orthopedic surgeons. Treatment principles include thoroughly debridement and effectively reconstruction of bone defect to achieve expected functional outcomes. At present, the commonly used methods for the treatment of femoral defect caused by chronic osteomyelitis include autologous or allogeneic bone transplantation, free fibula transplantation, Masquelet technique, Ilizarov technique and bone tissue engineering [1-5]. Compared with other available treatment options, the Ilizarov bone transport technique has the advantages of bone defects reconstruction and repair of soft tissue defects, radically eliminating infection, deformity correction, and early weight bearing and functional exercise. However, the most important disadvantage of the Ilizarov bone transport technique is the long wearing time of the external fixator, which results in series of complications. How to reduce the time spent on external fixation and reduce related complications is a major concern that needs to be solved urgently. Catagni et al. [6] suggested that double level bone transport can significantly shorten the treatment time for tibial bone defect, and reduce the number of additional operations and related complications. In this study, we compared the lengthening index, mineralization index, external fixation index, complications and treatment results of single level and double level bone transport techniques in the treatment of femoral defect caused by chronic osteomyelitis and to compare the treatment outcomes of two different transport approach.

Patients and Methods

The inclusion and exclusion criteria

Inclusion criteria: (1) Patients aged 18 to 60 years old. (2) Femoral defect ≥ 3 cm caused by chronic osteomyelitis. (3) Patients who were treated with bone transport technique. (4) Follow up ≥ 2 years after removal of external fixator. Exclusion criteria: (1) Patients with neurological diseases and psychological disorders affecting the effect of surgical treatment and prognosis. (2) Patients with tumors, congenital developmental bone disease, metabolic bone disease and severe vascular disease; (3) Femoral bone defect <3 cm; (4) Patients with incomplete clinical data or loss of follow up.

Included patients

According to the inclusion and exclusion criteria, a total of 35 patients were included, there were 28 males and 7 females. The age ranged from 18 to 58 years, with an average of 30.89 ± 10.62 years old. The injury mechanisms were traffic accident (n=14), fall (n=9), falls from height (n=5), hematogenous infection (n=5), crush injury (n=1) and machine injury (n=1). The injured sites were left femur (n=17) and right femur (n=18). There were 19 patients with internal fixation and 16 patients with external fixation in the index surgery. The time from initial injury to undergoing bone transport operation ranged from 7 to 312 months, with an average of 68.14 ± 78.14 months. The number of previous operation times ranged from 1 to 5, with an average of 3.17 ± 1.32. All patients had varying degrees of knee dysfunction before surgery. According to the knee HSS score, 0 cases were excellent, 10 cases were good, 12 cases were fair, and 13 cases were poor. According to the different transport level, the patients were divided into two groups, including 16 cases of single level bone transport and 19 cases of double level bone transport. The comparison of preoperative data between the two groups is shown in Tables 1 and 2.

Table 1. Comparison of demographic data of include patients

Variables	**Single level group(n=16)**	**Double level group(n=19)**	**Statistic**	**P values**
Sex ratio(male/female)	4.33(13/3)	3.75(15/4)	-	0.602*
Age(years, `x ± s)	31.63 ± 10.86	30.26 ± 10.68	t=0.373	0.712+
Smoking (yes/no)	8/8	11/8	-	0.506*
Injury site (e.g., left/right)	7/9	10/9	-	0.738*
Cause of injury (e.g. car accident injury/fall injury/other)	6/9/1	8/5/6	-	0.107*
Primary fixation (e.g. internal/external fixation)	8/8	11/8	-	0.740*
Number of previous surgeries (times, x ± s)	2.75 ± 1.00	3.53 ± 1.47	t=-1.793	0.082+
Duration from initial injury to bone transport operation (months, x ± s)	54.00 ± 78.51	78.47 ± 79.47	t=-0.913	0.368+
HSS score of knee joint (excellent/good/moderate/poor)	0/5/6/5	0/5/6/8	W=271.500	0.562#

*, Fisher exact test

+, independent sample t-test

, Wilcoxon rank sum test

Table 2. Comparison of postoperative data between Single and Double-level bone transport group

Variables	Single level group (n=16)	double level group (n=19)	Statistic	P values
Defect length(cm, `x ± s)	7.13 ± 2.16	12.32 ± 3.60	t=-5.268	0.000+
Bone transport time(days,x ± s)	99.00 ± 31.17	100.53 ± 33.28	t=-0.139	0.890+
Bone lengthening index (days/cm)	13.87 ± 0.65	8.10 ± 0.44	t=31.189	0.000+
Consolidation time (month, `x ± s)	10.30 ± 3.72	11.07 ± 4.05	t=-0.584	0.563+
Consolidation index (month / cm)	1.45 ± 0.30	0.88 ± 0.14	t=6.852	0.000+
External fixation time (months, x ± s)	17.04 ± 5.03	17.08 ± 5.26	t=-0.020	0.984+
External Fixation Index (months/cm)	2.42 ± 0.25	1.38 ± 1.11	t=15.263	0.000+
HSS score of knee joint (excellent/good/moderate/poor)	0/2/10/4	0/3/9/7	W=276.000	0.658#

+, independent sample t-test

, Wilcoxon rank sum test

Preoperative preparation

According to the X ray and Computed Tomography (CT) image, the location and size of infected bone were accurately measured and evaluated, the osteotomy level and transportation direction were determined, the appropriate length external fixator and placement of Schanz screw was selected. According to the preoperative imaging measurement of the contralateral femur, combined with the length of the bone defect of the affected side, the distance to be transported and the length to be corrected were precisely calculated.

Surgical technique

After obtaining satisfactory surgical position under general or epidural anesthesia, the incision was made according to the previous surgical scar (if there was no operation, the anterolateral longitudinal incision was performed), the subcutaneous tissue was separated, and the infection site was exposed. The samples were taken and send for bacterial culture and drug sensitivity test to guide the use of antibiotics after operation. Plate or bone cement at the infected site from previous operation were removed, radical debridement to remove all necrotic and infected bone and soft tissue until the medullary cavity is unobstructed and cortical bleeding, so called “paprika sign” [7]. After the radical debridement, an external fixator was assembled and placed on the anterolateral thigh with the knee in passive flexion position. Under fluoroscopy, 3 Schanz screws were placed below the lateral greater trochanter of the femur at intervals of 2 cm, and 3 Schanz screws were placed on the femoral condyle in the same way. After the placement of Schanz screws, it was connected and fixed with the external fixator. Sliding bolt was installed on the connecting rod, and 2 Schanz screws were placed perpendicular to the long axis of the proximal or/and distal end of the defective femur. Then the infected bone segment was excised, and the percutaneous minimally invasive osteotomy was performed using a wire saw at the pre-planned osteotomy site.

Postoperative management

Antibiotic was adjusted for at least 6 weeks based on bacterial culture and drug susceptibility results. Passive knee and ankle exercises were started on the first postoperative day, and early weight bearing was encouraged. Bone transport started after a latency period of 7 to 10 days. The rate and rhythm of single level group was 0.25 mm/four times/day. In the double level group, when transported in the same direction, the sliding bolt near to the defect was transported by 0.5 mm/four times/day, while the bone segment far away from the defect was transported by 0.25 mm/four times/day. For the converging bone transport, each bone segment on either side was transported at a rate of 0.25 mm/four times/day. Surgical illustration of double level is demonstrated in Figure 1. During the bone transport period, the patients were followed up to the outpatient clinic every 2 weeks, and physical examination and X ray were performed to record and deal with the postoperative complications of bone transport. After the docking site was in contact, continue to transport for 3-5 days to fully pressurize the contacting site. Removal of external fixator should meet the following criteria [6]: The external fixator was axially dynamized when X ray showed Docking site fusion and the area of bone regeneration showed continuous cortical bone on at least three sides in the anteroposterior and posterior views. After the external fixator is removed, protection with a long leg plaster or a protective brace for 1-2 months and walking with crutches for at least 3 weeks to avoid fracture at the docking site or bending of the bone regeneration area. For more details of the whole procedures in both groups, please refer to Figures 2 and 3.

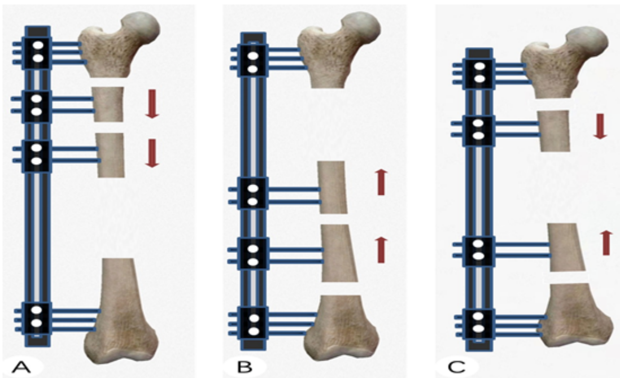

Figure 1. Surgical illustration of double level bone transport of the femoral defect. (A) Double-level bone transport from proximal to distal. (B) Double-level bone transport from distal to proximal. (C) Double-level bone transport in converging direction.

Figure 2. A 21-year-old man presented with post-traumatic osteomyelitis of the left femur caused by a traffic accident injury. (A,B) Anteroposterior and lateral radiographs of the femur at admission. (C,D) Bone defect of 13 cm on radiographs 10 days after surgery (7-day latency). (E) After twenty-eight months, both the docking site and the regeneration of distracted region showed that met the mineralization criteria, but the femur length was about 10 cm shorter than that of the contralateral side. (F,G) Radiographs on the day of removal of the external fixator. (H,I) Two months after the removal of the external fixator, limb lengthening was performed by osteotomy at the distal femur due to the difference in limb length. (J,K) Four months later, the limb lengthening was completed, the external fixator was removed, and the bone mineralization in the extended regeneration area was good. (L) The external fixator was

removed for 3 months on radiographs, and the bone mineralization was excellent. (M) Acceptable functional outcomes at last visit.

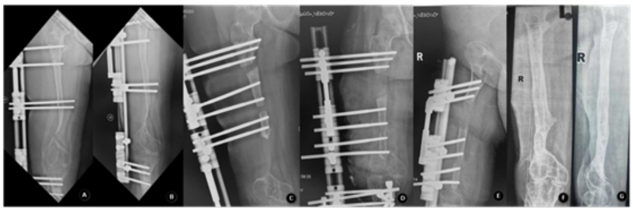

Figure 3. A 23-year-old woman presented with osteomyelitis of the right femur after a fall at the age of 13 years. (A,B) Anteroposterior and lateral radiographs of the femur at admission. (C) An X-ray taken 2 weeks after double-level bone transport. (D,E) Six months later, radiography showed contact at docking site and bone transport was completed. (F,G) Excellent regenerate mineralization at last visit after removal of the external fixator.

Observation and evaluation indicators

Postoperative bone defect length, bone transport time, mineralization time of the distracted region, external fixation time, external fixation index, postoperative knee HSS score and complications were recorded. According to Paley's description [8], complications are classified into problems, obstacles, and true complications. At the last follow up, ASAMI (Association for the study and application of the method of Ilizarov) scoring standard was used to evaluate the bony and functional results [9].

Statistical methods

The statistical software SPSS 25.0 of IBM Company was used for analysis. The measurement data were expressed by mean ± standard deviation, independent sample t test was used for comparison between groups, Fisher exact test was used for comparison of count data between the two groups, Wilcoxon rank sum test was used for comparison of grade data between the two groups, and p value<0.05 was regarded as statistically significant.

Results

All included patients were followed up for 24-76 months, with an average one of 44.77 ± 14.72 months. The length of intraoperative bone defects ranged from 3.5 to 20 cm, with an average of 9.94 ± 3.97 cm. The bone transport time ranged from 48-183 days, with an average of 99.83 ± 31.87 days. The mineralization time of distracted region was 5.3-19.7 months, with an average of 10.72 ± 3.87 months. The removal time of the external fixator was 9.4-28.7 months, with an average of 17.06 ± 5.08 months. The external fixation index was 1.21 to 2.87 months/cm, with an average of 1.86 ± 0.55 months/cm. According to the postoperative knee HSS score, the results were excellent in 0 cases, good in 5 cases, fair in 19 cases and poor in 11 cases.

A total of 25 patients occurred with different degrees of pin tract infection, of which 24 cases were effectively controlled by regular pin tract dressing and oral antibiotics, and 1 case with severe pin tract infection was managed by replacement of the Schanz screw (s). The axial deviation occurred in 4 cases, which was corrected by surgical intervention. Delayed union occurred in 6 cases at the Docking site, of which 3 had bone healed with autologous bone grafting, and remaining 3 reached bone healing by "accordion technique [10]". The difference of limb length in 3 cases was more than 2.5 cm. Among them, 1 case underwent limb lengthening to reach limb equality in the second stage, and the other 2 cases used customized internal high rise shoes to correct shortening. 1 case had a refracture of the femoral docking site 6 months after removal of the external fixator, which healed postoperatively by bone grafting and internal fixation. No serious complications such as neurovascular injury, septic arthritis, or deep venous thrombosis occurred in all patients. The complications of single level bone transport group and double level bone transport group are compared according to Paley classification [8] in Table 3.

Table 3. Comparison of complications by Paley classification between the Single and double-level bone transport group

Complications	Single Level Group			Double Level Group			Total
	Problems	Disorders	True Complications	Problems	Disorders	True Complications	
Pin tract infection	12	0	0	12	1	0	25
Pin loosening	0	0	0	0	1	0	1
Axial deviation	0	2	0	0	2	0	4
Delayed union	2	1	0	1	2	0	6
Difference of limb length ≥ 2.5(cm)	0	0	1	0	0	2	3
Refracture	0	0	1	0	0	0	1
Total*	14	3	2	13	6	3	40
P- values:0.784							
*,Fisher exact test							

According to ASAMI bone and functional criteria, ASAMI bone score was excellent in 21 cases, good in 10 cases, fair in 3 cases, and poor in 1 case, functional score was excellent in 0 cases, good in 13 cases, fair in 18 cases, and poor in 4 case. The excellent and good rate of bone evaluation was 88.6%. The excellent and good rate of limb function evaluation was 37.1%. The comparison of the evaluation of ASAMI bone and functional results between Single and double level bone transport group is shown in Table 4.

Table 4. Comparison of the evaluation of ASAMI bone and functional results between Single and double-level bone transport group

Outcomes	Bone results		Functional results	
	Single Level Group	Double Level Group	Single Level Group	Double Level Group
excellent	8	13	0	0
good	6	4	7	6
fair	1	2	8	10
poor	1	0	1	3
Wilcoxon rank sum test	W=315.000 P=0.305		W=262.500 P=0.349	
Fisher exact test *	P=0.630		P=0.503	
*, excellent and good(Satisfactory;fair and poor(Unsatisfactory)				

Discussion

The treatment principle of chronic osteomyelitis is to thoroughly debride the infected site and reconstruct and repair the bone defect through effective methods. Therefore, several surgical approaches have been proposed in term of reducing the time spend on external fixator and gradually applied in clinical practice. Studies have shown that bone transport using external fixator combined with intramedullary nailing [11] or bone transport and then applying intramedullary nailing [12] to reduce the external fixation time and lowering the risk of axial deviation, regenerated bone fracture and joint stiffness. However, the use of intramedullary nails could potentially increase the risk of bone infection, the cost of implants is high and additional surgery is required to remove the intramedullary nail, which increase the economic burden and secondary trauma. In a study by Paley et al. [13], 19 patients with tibial defects were treated with bone transport, of which 6 patients underwent two level bone transport. The results showed that the average external fixator index of single level bone transport patients was 2.1 months/cm, double level bone transport patients was 1.2 months/cm. The external fixation index of single level bone transfer patients was nearly twice as much as that of double level patients. In a comparative study of single level and multilevel bone transport with long bone defects, Borzunov [14] also concluded that the bone lengthening time and the consolidation time in multi-level patients can be reduced by 2.5 times and 1.3-1.9 times. Similar studies have been also performed by Yushan et al. [15] and the results show that the lengthening rate, external fixation index, and mineralization time were significantly reduced in the double level group, and the functional results of the double level group were better than those of the single level group. In our study, the size of femoral defect in the double level group was longer than that in the single level group, while the lengthening index, external fixation index, and mineralization index were lower than those in the single level group, and there was no difference in bone results and functional results between the two groups, which indicate that double level bone transport can potentially reduce the time spend on external fixator and shortening the consolidation time.

Catagni et al. [6] reported 86 patients with tibial bone defects (45 cases treated with single level bone transport and 41 cases with double level bone transport). In addition to the above conclusions, they considered that double level bone transport can also reduce the number of additional operations and ture complications. Sala et al. [16] made a comparative study of single level and double level bone transport, and also concluded that shortening the external fixation time can minimize the risk of complications such as nail infection, loosening and joint stiffness. However, each additional segment of the transported bone level and side slider can potentially increase the occurrence of pin tract infection and distraction related complications [6]. This means that double level bone transport is more prone to complications than single level transport. This seems to contradict the conclusion of Sala et al. In a meta-analysis of a total of 426 cases in 22 studies by Yin et al. [17], the average bone defect was 6.527 ± 1.882 and the average complication was 1.567 ± 0.901. In a study by Zhang et al. [18] of bone transport in 41 cases with large femoral bone defect, the length of bone defect was 6~17 cm, with an average of 10.1 cm, and the complication rate per case was

1.22%. In our study, the length of femoral bone defect in 35 patients was 3.5 to 20 cm, with an average of 9.94 ± 3.97 cm, and the average complication per case was 1.23, which was basically similar to the above results. Among them, the complication of each patient in the single level group was 1.19 and that of the double level group was 1.26 (P>0.05), indicating that there was no statistical difference in complications between the two groups, and the double level bone transport did not increase the occurrence of complications. Catagni et al. [6] believe that the reason is that faster bone regeneration and relatively early removal of the external fixator reduce the incidence of complications.

Marsh et al. [19] suggested that at least half of the patients experienced a pin track reaction from the use of the external fixator. In our study, 25 patients developed pin tract infection with an incidence of 71.4%. Previous studies [18] suggested that pin tract infection is related to the patient's bone quality, immunity, education level, and the stability of the external fixator. According to our experience, pin loosening, intraoperative thermal damage, and prolonged external fixation time are considered as major contribution to the occurrence of the pin tract infection. Preventing osteoporosis, nutritional therapy, improving patients' immunity, educating patients on the concept of asepsis and regular reexamination can reduce the occurrence of pin tract infection. In addition, stick to the principle of pre drilling and the manually inserting Schanz screw could be beneficial to reduce the incidence of pin tract infection.

Excessive muscular traction during bone transport of femoral defect may result in muscle contractures or adhesions and consequently leads to inevitable knee joint stiffness. In a report by Zhang et al. [18], 14 cases experienced knee stiffness and decreased knee range of motion, and 8 cases had knee joint dysfunction before operation. In the study of Pallaro et al. [20], 7 cases of femoral defect were treated with bone transport technique and result in limited range of knee flexion motion. In our study, all cases suffered knee joint dysfunction before bone transport operation which may contributed to multiple index surgeries, prolonged immobilization and lack of active exercise caused by intolerable pain. Thompson [21] believes that the scar and fibrosis of the vastus intermedius muscle affect the extensibility and contractility of the muscle, which is the main cause of knee joint stiffness. Nicoll [22] concluded that adhesion from the deep surface of the patella to the femoral condyles, fibrosis and shortening of the lateral expansions of the vasti and their adherence to the lateral aspects of the femoral condyles, and actual shortening of the rectus fenioris itself are also the main causes of knee stiffness. Therefore, they believe that quadriceps myoplasty can effectively relieve knee stiffness and improve the quality of life of patients. In this study, the knee joint HHS score at last clinical visit were excellent in 0 cases, good in 5 cases, fair in 19 cases and poor in 11 cases and there was no significant difference between the two groups regarding the knee joint scores. Preoperative communication with patient and provide full understanding of treatment outcome, especially to inform patient about less likely of recovering the knee joint function is utmost important while lower patient's expectation. Future study should be focused on improvement of knee joint function on patients with femoral defect caused by chronic osteomyelitis underwent bone transport technique, such as quadriceps myoplasty or total knee replacement.

The limitations of our study including retrospective design, small sample size in single center study with a low level of evidence. The results of our study need further confirmation in large sample multi center prospective randomized controlled trials. Besides, comparative studies is also needed to compare the efficacy of bone transport using Ilizarov technique and combination of external fixator with intramedullary nailing.

Conclusion

In summary, single level and double level bone transport techniques are both effective for the treatment of femoral defect caused by chronic osteomyelitis. Double level bone transport could significantly shorten the time of external fixator frame, and there was no significant difference in the incidence of complications between double and single level bone transport, so it would not increase the incidence of related complications.

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