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TRAUMA SURGERY

Segmental transports for posttraumatic lower extremity bone defects: are femoral bone transports safer than tibial?

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Abstract
Background The long-term outcomes following femoral and tibial segment transports are not well documented. Purpose of the study is to compare the complication rates and life quality scores of femoral and tibial transports in order to find what are the complication rates of femoral and tibial monorail bone transports and if they are different?
Methods We retrospectively analyzed the medical records of 8 femoral and 14 tibial consecutive segment transports performed with the monorail technique between 2001 and 2008 in our institution. Mean follow-up was 5.1 ± 2.1 years with a minimum follow-up of 2 years. Aetiology of the defects was posttraumatic in all cases. Four femoral (50%) and nine tibial (64%) fractures were open. The Short Form-36 (SF-36) health survey was used to compare the life quality after femoral and tibial bone transports. The Mann–Whiney U test, Fisher exact test, and the Student's two tailed t-test were used for statistical analysis. $P \leq 0.05$ was considered to be statistically significant.
Results The tibial transport was associated with higher rates of severe complications and additional procedures (1.5 ± 0.9 vs. 3.4 ± 2.7, $p = 0.048$). Three patients of the tibial group were amputated because of recurrent infections and one developed a complete regenerate insufficiency that was treated with partial diaphyseal tibial replacement. Contrary to that none of patients of the femoral group developed a complete regenerate insufficiency or was amputated.
Conclusions Tibial bone transports have a higher rate of complete and incomplete regenerate insufficiency and can more often end in an amputation. The authors suggest systematic weekly controls of the CRP value and of the callus formation in patients with posttraumatic tibia bone transports. Further comparative studies comparing the results of bone transports with and without intramedullary implants are necessary.

Keywords Bone transport · Monorail technique · Femoral and tibial complications

Introduction

Surgical treatment of large bone defects involving the lower extremity has always been challenging for the orthopedic surgeons. Advances in diagnostic imaging, chemotherapy and especially in operative reconstructive techniques, since the introduction of callus distraction by Ilizarov in 1952 have increased the popularity of limb-salvage surgery [10]. A milestone in the history of callus distraction is the introduction of the monorail technique (segmental bone transport over intramedullary nail) by Raschke et al. in 1992 [19]. Reported advantages of monorail transport are fewer external fixator associated complications, earlier rehabilitation, reduced risk of mal-alignment and refracture, and more rapid return to normal joint motion and activity [5, 12, 17].

Our study aimed mainly at answering the following questions: (1) What are the complications of femoral and tibial monorail transports? (2) Can the site of bone transport influence the prognosis and the outcome of the

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procedure? (3) Is the life quality affected by the localization of the defect?

Materials and methods

We obtained the medical records of all patients who underwent a monorail segmental transport for bone defects from January 2001 to April 2008. Permission to review the medical records and to contact potential subjects was obtained from the ethical board (#644 – 05/01/2010). Patients were excluded if they were less than 18 years old at the time of the follow-up or if they had a less than 2 years follow-up. The patients were divided into two groups; the femoral and tibial groups with 8 and 14 patients, respectively. The mean age of the patients at the date of the bone transport was 38.8 ± 13.3 years for the femoral group and 44.6 ± 14 years for the tibial group. The size of the defect was 6.8 ± 2.8 and 8.0 ± 3.0 for the femoral and tibial group, respectively. Etiology of all the bone defects was posttraumatic (Table 1). Persistent infections defined by positive microbiological cultures from the drainage fluid and elevated CRP levels for more than 6 weeks were treated with repeat debridements, removal of the intramedullary nail, and administration of antibiotics for 6 weeks. Deformities were defined as pathological angulations of 5° or more in frontal or sagittal plane according to Paley et al. [16]. Healing of the bone transport was achieved with bony union and the absence of infection at the time of follow-up.

We attempted to contact by mail all patients who met our inclusion criteria: the letter explained the study's purpose and invited the recipient to participate in this study. If there was no response, attempts were made to contact them by telephone. The questionnaire we used was the Short Form-36 (SF-36) health survey. The SF-36 is a standardized test, which is divided into eight areas (physical function, role physical, bodily pain, general health, vitality, social function, role emotional, and mental health) [3, 9]. The SF-36 responses of the femoral group were compared with those of the tibial group. No patients were lost to follow-up.

The result of the SF-36 questionnaire and complications was recorded and compared for femoral and tibial bone transports. Complications were classified using the system of Dahl et al. [2] into minor, serious, and severe. Minor complications do not affect the final outcome or require extensive intervention. Complications which are major and temporary or minor but permanent were considered serious. Severe complications are those that require unplanned major surgery or result in major permanent sequelae.

Operative technique [5, 19]

The fracture was initially stabilized with an external fixator. Infection of the bone and soft tissue was then treated with serial debridements. The dead space was filled with custom-made antibiotic impregnated polymethylmethacrylate cement spacer. Complete closure of the soft tissue with local or free myocutaneous flap was accomplished before beginning the bone transport. When the C-reactive protein level returned to the normal level and the microorganisms were absent from the intra- and postoperative cultures, an osteotomy was performed with an osteotome and antegrade intramedullary nail was inserted and statically locked. Two Schanz screws were inserted proximal to the level of the osteotomy site and two distal to it on the segment to be transported. Contact of the nail with the Schanz screws should be avoided in order to avoid the spreading of pin tract infections along the intramedullary nail [12]. Distraction was started in the fifth postoperative day in a rate of 1 mm/day. After the transport was completed, the fixator was removed in most cases. A satisfactory callus consolidation presents, however, a condition for removing the external fixator. Bone grafting and plate-screw fixation of the docking site were not performed as a routine procedure, but only by retarded bone healing.

Table 1 Preoperative data

	Femoral group ($n = 8$)	Tibial group ($n = 14$)	p value
Age in years	38.8 ± 13.3	44.6 ± 14.5	0.363
Defect length in cm	6.8 ± 2.8	8.0 ± 3.0	0.344
Chronic osteitis	5	11	0.624
Sex: female	2	3	1.0
Open fractures	4	8	0.662
Nicotine abuse	2	4	1.0
Operations prior to bone transport	3.0 ± 3.1	4.5 ± 2.9	0.267

Table shows that both groups are comparable

Statistical analysis

Statistical significance was evaluated between different groups using Mann–Whitney *U* test and Student's two tailed *t*-test for continuous data, while Fisher's exact test and Pearson chi-square were used for categorical values. A p value ≤ 0.05 (two tailed) was considered to be statistically significant. All statistical analyses were performed using SPSS (SPSS 15.0, SPSS Inc., Chicago, IL, USA). All values are presented in the form of mean ± SD (standard deviation).

Results

Patients were followed up for an average 5.1 ± 2.1 years. No statistically significant differences were found between both groups regarding percentages of smokers, number of previous surgeries, rates of open fractures, or chronic infections. Table 2 summarizes the results of our study. The femoral group had 9 complications in 8 patients; 4 minor complications, 5 serious complications, and no severe complications. Two patients had superficial pin tract infections (Grade I and II according to the Paley classification [16]) that were treated successfully with oral antibiotics and were considered minor complications. Transient knee flexion contractures ($n = 2$) were also considered minor complications. Serious complications were reinfection of the wound ($n = 2$) that required debridement, a dislocation of a Schanz screw, one deep pin tract infection and a varus deformity of more than 5° that also required surgery. The tibial group had 16 complications in 14 patients. Four of them were severe (3 persistent osteitis and 1 complete regenerate insufficiency), 9 serious (2 wound infections, 3 incomplete regenerate insufficiencies, 1 valgus deformity and 3 pin associated complications including loosening and deep infections of the Schanz screw), and 3 minor complications (2 superficial pin tract infections and one transient knee flexion contracture). The delayed union of the docking site that required a docking operation was not considered as a true complication, because in many institutes this procedure is routinely performed at the time the fixator is removed [12]. Two patients from the femoral and seven from the tibial group had docking operations.

All the femoral patients achieved healing while 4 tibial patients did not heal. Three of them were amputated because of recurrent infections and one had a complete

Table 2 Results of the study

	Femoral group ($n = 8$)	Tibial group ($n = 14$)	p value
Healing	8	10	0.254
Amputation	0	3	0.273
Complete regenerate insufficiency	0	1	0.462
Deformity	1	1	1.0
Number of additional surgical procedures*	1.5 ± 0.9	3.4 ± 2.7	0.048
Operation requiring pin tract complications (infection, loosening, dislocation, or breakage of the Schanz screws)	2	3	1.0
Bone grafting operations for partial regenerate insufficiency or within the context of a docking operation*	2	11	0.05
Complications	9 (113%)	16 (114%)	
Minor	4	3	
Serious	5	9	
Severe	0	4	
SF-36			
Physical functioning	55 ± 31	56 ± 24	0.927
Physical role functioning	69 ± 35	48 ± 26	0.123
Bodily pain	61 ± 31	57 ± 26	0.738
General health	52 ± 22	59 ± 23	0.422
Vitality	53 ± 25	56 ± 24	0.818
Social functioning	70 ± 35	63 ± 33	0.602
Role: emotional	80 ± 34	87 ± 28	0.699
Mental health	73 ± 24	73 ± 19	0.952

* Indicates statistical significance

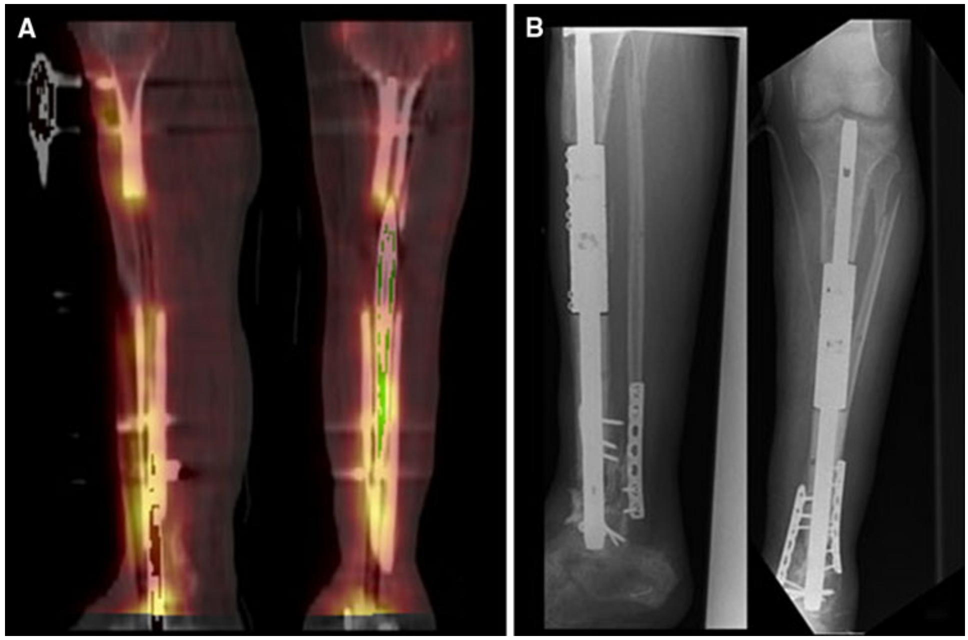

Fig. 1 Complete regenerate insufficiency. **a** SPECT/CT showing complete regenerate insufficiency 16 months after completion of the transport. **b** Partial tibial diaphyseal endoprothesis

regenerate insufficiency that was successfully treated with a partial diaphyseal replacement (Fig. 1). All the amputated patients had open fractures and chronic infections. Three out of the four patients who did not heal were smokers.

The number of the required additional procedures was also significantly higher in the tibial group (1.5 ± 0.9 vs. 3.4 ± 2.7, $p = 0.048$). Twelve bone grafting operations for incomplete regenerate insufficiency or in the context of a docking operation were performed in the tibial group and just three in the femoral group ($p = 0.05$, Fig. 2). The number of surgeries required for the treatment of pin tract-associated complications, such as pin tract infections, loosening or breakage of the Schanz screws, was not significantly different.

Comparing the SF-36 scores, we could not show any statistically significant differences in none of the eight areas of life quality (Table 2).

Discussion

For the treatment of open fractures or posttraumatic infections extensive debridements are usually required. This results in large bone defects that can be treated by various complex reconstructive procedures. Callus distraction allows the simultaneous treatment of large bone defects and deformities with minimal soft tissue trauma [4, 18]. Bone transport over an intramedullary rod shortens the external fixation period, because the regenerated bone is

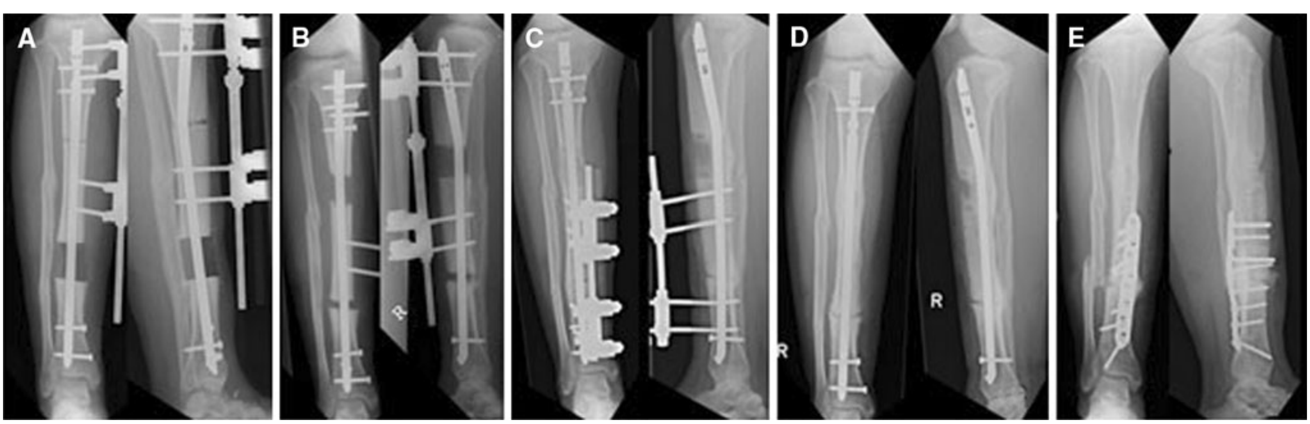

Fig. 2 Pseudarthrosis of the docking site. **a**, **b** Staged tibial bone transport in a 29-year-old patient with 5 cm bone defect. **c** Beginning of the consolidation. **d** Pseudarthrosis of the docking site 6 months after removal of the external fixator. **e** Treatment of the Docking site nonunion with debridement, bone grafting and plate-screw fixation

internally supported and thus improves the patient comfort [14, 15, 19]. To the best of our knowledge, this study is the largest series published so far for segmental transports using the monorail technique for femoral and tibial bone defects.

Unfortunately, our study has some limitations. First, the femoral group was much smaller in number in relation to the tibial and therefore comparisons between both groups regarding complication rates and the SF-36 scores cannot yield solid conclusions. Second, the overall small sample size can predispose to type II errors in our statistical analyses.

There was an obvious difference, although not statistically relevant, in the rates of amputations between the femoral (0%) and tibial groups (21%). All of these patients had multiple risk factors, such as chronic infections and open fractures. One patient was incompliant, because of a psychiatric disorder and did not comply with the postoperative workup as planned. Two out of the three patients were smokers.

The lower incidence of bone grafting surgeries in the femoral group could be explained through the better blood supply of the femur. Almost the whole surface of the femur is surrounded by well-perfused muscles. Contrary to that, only the two-thirds of the tibia surface have direct contact with muscle tissue and its anteromedial surface is completely subcutaneous. Furthermore, it is known that nonunions after open fractures are more often in the tibia than in the femur [1]. The overall rate of nonunion for the skeleton has been estimated at 3%. In the tibia, however, the nonunion rate is much higher, having been reported to be as high as 9% for unselected cases and 75% for displaced, open, and comminuted fractures [8]. One of the major determining factors in the development of nonunion is the degree of soft tissue injury and interruption of osseous blood supply at the time of the initial injury [1]. Additionally, bone regenerate for distraction osteogenesis heals more rapidly in the femur compared to the tibia [6, 7]. Although three amputations in the tibial group are considered a poor result, all patients were able to perform activities of daily living.

Outcomes of segmental bone transports over an intramedullary nail have been reported by other authors [12, 14, 15, 19]. Kocaoglu et al. [12] reported the results of treatment of 13 segmental bone defects due to chronic osteomyelitis. Six patients had femoral defects and seven tibial. Two patients had failures in the form of recurrent infections and both involved the tibia. After repeated debridements and removal of the intramedullary nail, the infection could be eradicated and all patients achieved complete union at the time of the final follow-up.

Tibial segmental bone transports using the monorail technique are associated with higher rates of amputations and additional procedures than femoral and should be followed up very closely (e.g. weekly controls). Two main problems should always be in mind; the risk of deep infections and the condition of the regenerate [13, 17]. Any pin tract infection should be recognized early and treatment with local debridement or antibiotics should not be delayed because of the risk of expansion of the infection to the whole medullary cavity through the intramedullary nail [17]. If signs of deep infection are detected (redness, increasing pain, swelling, and rise in the laboratory infection parameters), we recommend the immediate admission of the patient in the hospital. Surgical debridement is the mainstay of treatment in these cases with parenteral admission of antibiotics according to the results of the microbiological cultures. In cases with aggressive or recurrent infections not responding to this workup, we recommend the removal of the intramedullary nail, the application of an Ilizarov fixator and the parenteral administration of antibiotics for at least 3 weeks.

The condition of the regenerate should also be assessed and documented with each follow-up visit using plain radiographs and ultrasound examinations. In any case of insufficient bone regenerate, every effort should be firstly directed to exclude deep infections as a causative factor [16]. If infection is excluded, we have many treatment options, such as slowing up the distraction rate, or completely stopping the distraction for a while, going reverse and then forward one or more times (accordion maneuver) and resorting finally to bone grafting with or without the use of osteogenic protein 1 [11, 16].

In conclusion, the attendant doctor should be particularly alert in this group of patients and react immediately to any suspicion for deep infection or the presence of insufficient callus formation. Further comparative studies comparing the results of bone transports with and without intramedullary implants are necessary.

Conflict of interest statement There was no financial support for this study. None of the authors have received or will receive benefits for professional or personal use from a commercial party related directly or indirectly to the subject of this article. Each author certifies that he has no commercial associations (e.g, consultancies, stock ownership, equity interest, etc.) that might pose a conflict of interest in connection with the submitted article.

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