RESEARCH ARTICLE

Outcomes of Megaprosthesis Reconstruction for the Salvage of Failed Osteoarticular Allograft Around the Knee implanted before Skeletal Maturity in Primary Bone Sarcoma: A Case-Series

Khodamorad Jamshidi, MD; **Wael** Ammar, MD; **Khalil** Kargar Shooroki, MD; **Alireza** Mirzaei MD

Research performed at Shafa Orthopedic Hospital, Iran University of Medical Sciences

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Abstract

Objectives: Functional expectations following the salvage of a failed osteoarticular allograft are poorly described. In this study, we aim to evaluate functional outcomes, implant survival, and complications of the megaprosthesis in salvaging a failed osteoarticular allograft around the knee.

Methods: We retrospectively reviewed the medical profiles of 21 skeletally mature patients who underwent megaprosthesis reconstruction to salvage a failed osteoarticular allograft around the knee implanted before skeletal maturity. The location of reconstruction was the proximal tibia in 13 patients and the distal femur in eight patients. Knee function was evaluated by the Musculoskeletal Tumor Society (MSTS) score and the Toronto Extremity Salvage Score (TESS).

Results: The mean age of patients was 16±1.7 years. The mean interval between the primary (allograft) and secondary (megaprosthesis) reconstructions was 59.4±23.6 months. At an average follow-up of 51.2 months, the mean knee range of motion was 101.2±15.6°. The mean MSTS score and TESS were 83.6±7 and 86.6±7.9, respectively. The mean limb length discrepancy was 2.5±1 cm before and 0.36±0.74 cm after the operation (P<0.001). Six postoperative complications (28.6%) occurred in this series, including one wound dehiscence, one periprosthetic fracture, two acute infections, one aseptic loosening, and one delayed periprosthetic infection. Only the last two complications required revision. Accordingly, the two- and five-year implant survivals were 95.7% and 90%, respectively.

Conclusion: Megaprosthesis is a viable option for salvaging failed osteoarticular allografts around the knee. It also provides the opportunity to correct the limb length discrepancy.

Level of evidence: **IV**

Keywords: Bone tumor, Knee, Oncologic prosthesis, Osteoarticular allograft, Salvage

Introduction

Currently, the limb salvage procedure is the procedure of choice for treating musculoskeletal tumors around the knee whenever appropriate margins can be achieved.[1] Several options are available for reconstructing the defect after resection of the tibia or femur. Osteoarticular allograft is the most frequently used option in skeletally immature patients. It has the advantage of preserving the articular surface and growth plate on the other side of the joint, which is particularly important in children. However, osteoarticular allograft reconstruction has a complication rate of 40% to 70% and a high likelihood of secondary surgery within six years after reconstruction.[2,3]

Several options are available to salvage a failed osteoarticular allograft reconstruction, including arthroplasty, allograft-prosthesis reconstruction, and

Corresponding Author: Alireza Mirzaei, Shafa Orthopedic Hospital, Tehran, Iran

Email: mirzaeialireza26@gmail.com

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oncologic prosthesis. Each technique has its advantages and disadvantages.[4-6] However, owing to the advances in megaprosthetic design, this salvage procedure has attracted much interest in the secondary reconstruction of a failed primary osteoarticular allograft reconstruction.[7,8]

Although the salvage of a failed osteoarticular allograft with a megaprosthesis is a common surgical procedure in many centers, the functional expectations of patients following this procedure are rarely reported. In addition, previous reports generally included a heterogeneous collection of weight-bearing and non-weight-bearing limbs, making interpreting outcomes more difficult.[4-6] In this study, we aimed to report the functional outcomes, complications, and survival of the oncologic prosthesis in the salvage of a failed osteoarticular allograft around the knee, which was implanted before the age of skeletal maturity.

Materials and Methods

The review board approved this case-series study of our institute. Before the surgery, comprehensive consent was obtained from the patients to use their medical data for publication. The medical profiles of patients with bone tumors who underwent secondary reconstruction for the failure of the primary osteoarticular allograft reconstruction between January 2010 and June 2020 were retrospectively reviewed.

The inclusion criteria were secondary reconstruction around the knee using an oncologic prosthesis, open physis on the other side of the ipsilateral extremity at the time of the primary reconstruction, and a minimum follow-up of two years. On the other hand, patients who underwent secondary reconstruction due to recurrence (n=3) or infection (n=1) were excluded from the study because these patients are expected to have inferior outcomes. Patients who lost to follow-up (n=2) were also excluded from the evaluation of outcomes. However, they were still included in the survival analysis (n=23) [Figure 1].

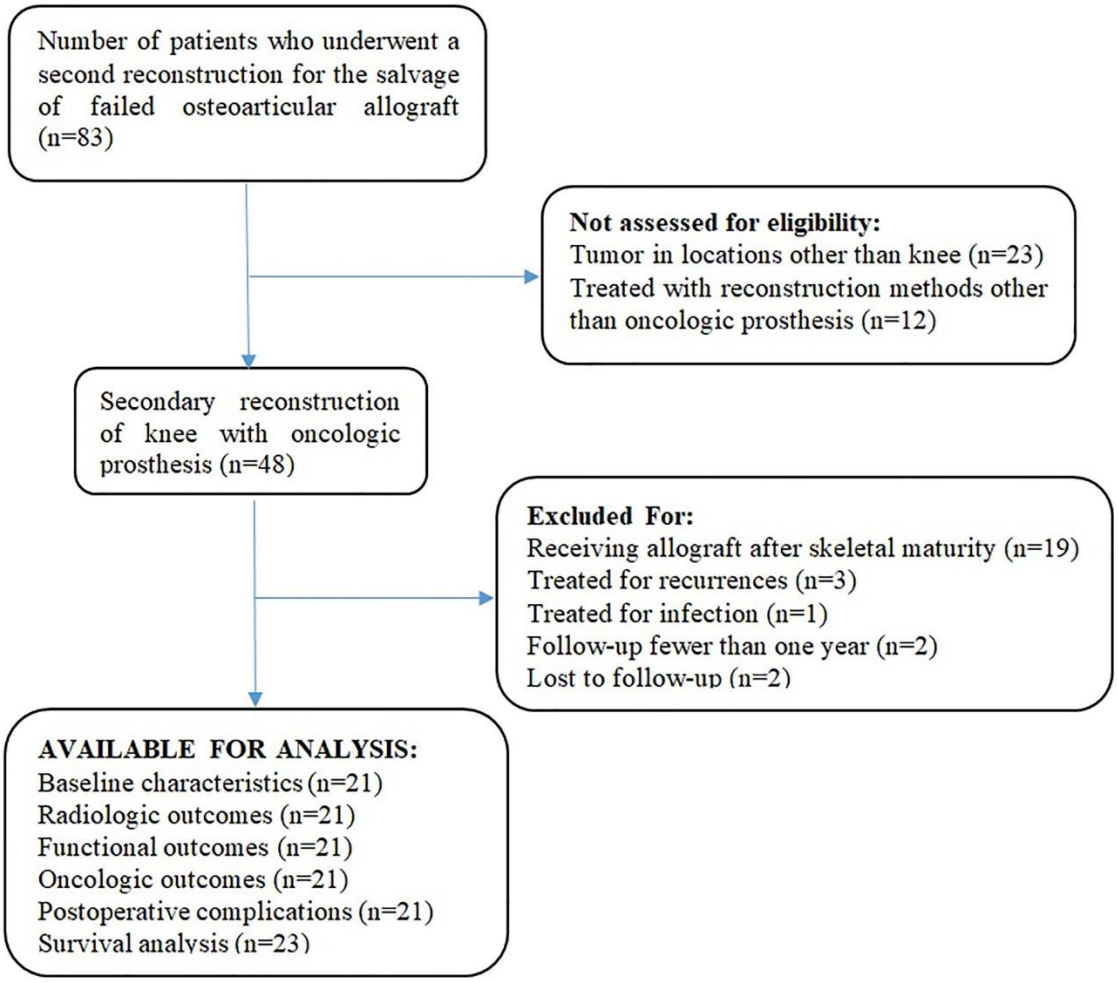

Figure 1. Flow diagram of the study

Surgical Procedure and Postoperative Protocol

All the surgeries were performed by the same senior orthopedic oncologist (KJ) in the same center (Shafa Orthopedic Hospital, Tehran, Iran). Using the previous incision and after the excision of the skin scar, the screws in the host bone were first removed. After elevating the plate, the allograft was removed precisely by releasing the soft tissue overlapped over it to avoid damaging the proximal tibial allograft. For patients who did not have a muscle flap in the primary reconstruction (n=4), this procedure was performed at the time of prosthetic reconstruction. We used the rotating-hinge Modular Universal Tumour and Revision System cementless prosthesis (MUTARS®; Implantcast GmbH, Buxtehude, Germany). The tibial modular canal was properly reamed with a hexagonal reamer. In addition, the hydroxyapatite-coated tibial stem was press-fit to the canal. We used a MUTARS trevira tube to cover the body of the prosthesis and anchor the patellar tendon to it [Figure 2]. The patellar tendon was attached directly to the transposed gastrocnemius and trevira tube to restore the extensor mechanism.[9] For patients with distal femur involvement (n=8), the surgical approach was determined by the location of the previous incision (anterolateral approach for three patients and anteromedial approach for five patients). Defects were reconstructed with a rotating-hinge MUTARS neurovascular bundle. Patients with proximal tibia involvement (n=13) were mostly treated through the previous anteromedial approach. For patients who had received a rotation flap of the medial head of gastrocnemius in the primary surgery (n=9), the incision was deepened through this muscle belly in the skin incision line without detaching the skin over it. The remaining muscle and the extensor mechanism were integrally separated from the cementless prosthesis in five patients [Figure 3] and with Stryker's Global Modular Replacement System® (GMRSTM, Stryker, Kalamazoo, MI, USA) in three patients. Limb discrepancy was compensated by increasing the length of the extension segment of the prosthesis as much as the soft tissue allowed.

After the operation, the knee was protected with a knee immobilizer for two weeks for the distal femur and for four weeks for proximal tibia reconstruction. Active and passive range of motion (ROM) were started after removing the knee immobilizer. Isometric exercises and toe-touch weight-bearing were also allowed from the third day after the operation. The patients were asked to remain on toe-touch weight-bearing for six weeks and partial weight-bearing for up to 50% of the body weight for another six weeks after the operation. Follow-up visits were performed every three months for the first year, every six months for the second year, and yearly afterward.

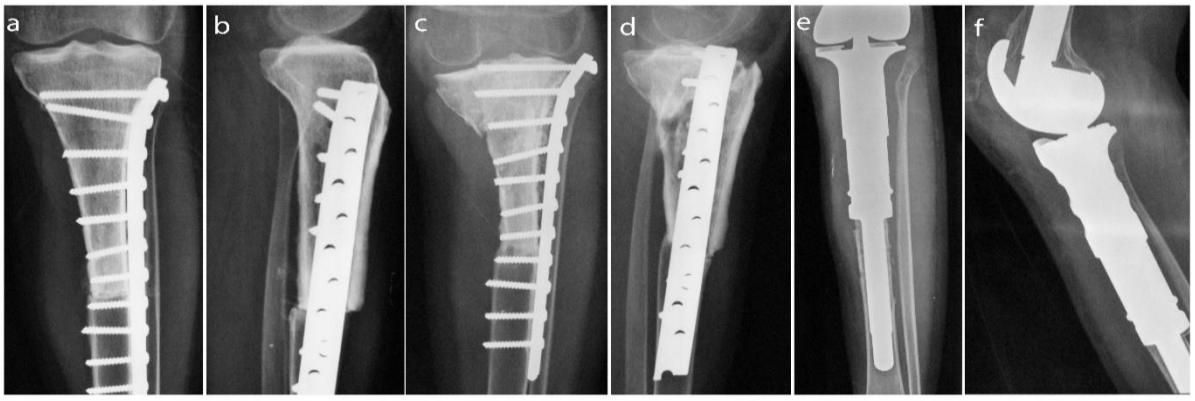

Figure 2. (A and B) Anteroposterior and lateral radiographs of osteoarticular allograft reconstruction of the proximal tibia in a 12-year-old boy; (C and D) Anteroposterior and lateral radiographs of the same patient after fracture of the osteoarticular allograft; (E and F) Anteroposterior and lateral radiographs after three years of implanting MUTARS cementless prosthesis

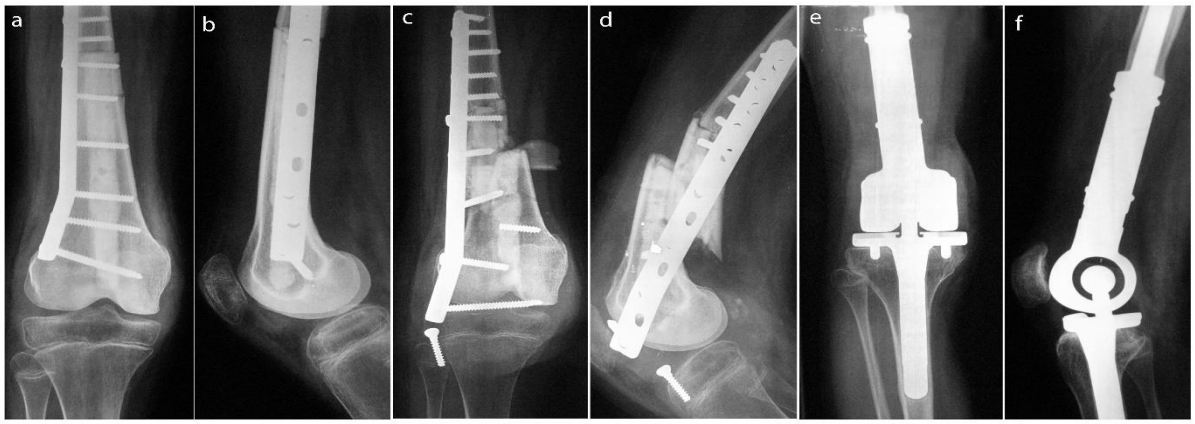

Figure 3. (A and B) Anteroposterior and lateral radiographs of osteoarticular allograft reconstruction of the distal femur in a 13-year-old boy; (C and D) Anteroposterior and lateral radiographs of the same patient after fracture of the osteoarticular allograft; (E and F) Anteroposterior and lateral radiographs after four years of implanting MUTARS cementless prosthesis.

Outcome Measures

For the evaluation of clinical outcomes, patients were called and asked to attend a final evaluation session. In this session, the ROM was evaluated using a standard goniometer. The knee functional outcome was evaluated objectively by the Musculoskeletal Tumor Society (MSTS) score and subjectively using the Toronto Extremity Salvage Score (TESS). According to the MSTS, each patient was given a score ranging from 0 to 30, which was finally presented as a percentage. A higher score was indicative of a better function.[10] Based on the TESS, each patient received a score ranging from 0 to 100, and a higher score was indicative of better function.[11] Limb length discrepancy was assessed with a digital X-ray scanogram, which uses a single radiographic exposure to both lower limbs. The lower limbs were positioned similarly, with both patella facing toward the ceiling, while a radio-opaque ruler taped to the table was located between the limbs.[12] Degenerative joint disease (DJD) was assessed with the Kellgren-Lawrence classification of osteoarthritis on lateral and anteroposterior radiographs of the knee. Accordingly, each patient was assigned a grade between 0 and 4, with grade 0 signifying no joint degeneration and grade 4 signifying the most severe one.[13]

The evaluation of outcomes was performed by an orthopedist who was not involved in the patients' care. Postoperative complications were extracted from the patients' profiles. Prosthesis failures were classified using the modified Henderson classification of megaprosthetesis failure.[14] Accordingly, the failures were categorized into mechanical and non-mechanical ones. The mechanical category was subcategorized into type 1 (soft-tissue failure), type 2 (aseptic loosening), and type 3 (structural failure). The non-mechanical category was subcategorized into type 4 (infection) and type 5 (tumor progression). Implant survival was defined as the presence of an implant in place at the time of examination, regardless of its condition.

Statistical Analysis

Statistical analyses were performed using SPSS software for Windows (version 16; SPSS Inc., Chicago, Ill., USA). Descriptive data were demonstrated with mean±standard deviation for quantitative variables and with numbers and percentages for qualitative variables. The Mann-Whitney U test was used to compare the mean MSTS score and TESS between the patients with femoral and tibial involvement. A comparison of limb length before and after the megaprosthetic reconstruction was made using the Wilcoxon signed rank test. Kaplan-Meier survival analysis was also used to evaluate the survival of megaprosthesis. A P-value of less than 0.05 was considered significant.

Results

Baseline Characteristics

Twenty-one patients who underwent secondary reconstruction using megaprosthetesis for the salvage of a failed osteoarticular allograft were included in the analysis. All of them underwent neoadjuvant chemotherapy, but not radiotherapy, before osteoarticular allograft reconstruction. For all patients, the primary (osteoarticular allograft) reconstruction was performed before the age of skeletal maturity (open physis). The study population included 12 males and nine females with a mean age of 16±1.7 years (range: 15-19). The mean time interval between the primary and secondary reconstruction was 43.3±23.6 months (range: 13-86). The secondary reconstruction was due to the fracture of the allograft in 10 patients (47.6%), subchondral collapse in three patients (14.3%), and DJD in eight patients (38.1%). The mean follow-up after the secondary reconstruction was 51.2±20.3 months (range: 24-84). The mean length of the prosthesis used to reconstruct the defect was 15.6±3.1 cm (range: 12-18). The characteristics and features of the patients are demonstrated in more detail in [Table 1].

Table 1. Characteristic features of the patients who underwent endoprosthetic reconstruction for the salvage of a failed osteoarticular allograft reconstruction

Feature	Mean±SD or number (%)
Age (year)	16±1.7
Sex	
• Male	12 (57.1)
• Female	9 (42.9)
Location	
• Proximal tibia	13 (61.9)
• Distal femur	8 (38.1)
Primary diagnosis	
• Osteosarcoma	19 (91.5)
• Ewing sarcoma	2 (8.5)
Resection size (cm)	13.4±1.6
Length of prosthesis (cm)	15.6±3.1
Reason for secondary reconstruction	
• Fracture	10 (47.6)
• Subchondral collapse	3 (14.3)
• DJD	8 (38.1)
Interval between the primary and secondary reconstruction (months)	59.4±23.6
Follow-up after the secondary reconstruction (months)	51.2±20.3

Outcome Evaluations

The mean prosthesis length was 15.1±2.7cm in the tibia and 16.3±3.7cm in the femur involvement. This difference was

not statistically significant (P=0.08). Before the secondary reconstruction, the mean limb length discrepancy of the patients was 2.5±1 cm (range: 1-5). At the final follow-up, the mean limb length discrepancy of the patients was 0.36±0.74 cm (range: 0-2.5) (P<0.001). The mean limb length discrepancy at the final evaluation was 2.3±1 cm (range: 1-4) for tibial reconstructions and 2.7±1.2 cm (range: 2-6) for femoral reconstructions. This difference was statistically significant (P=0.036).

The mean knee ROM at the final visit was 101.2±15.6° (range: 85-115). The mean final knee ROM was not significantly different between tibial and femoral reconstructions (102.1 vs. 99.2; P=0.09). Two patients with tibial reconstruction had extension lag (5º and 10º), and three patients had limited flexion (85°, 90°, and 100°). Two patients with femoral reconstruction also had limited flexion (90 and 110°). None of them had flexion contractures.

The mean MSTS score of the patients was 83.6±7% (range: 66.7-93.3), and their mean TESS was 86.6±7.9 (range: 75-95). The mean MSTS score was 84.2±6.8 in patients with femoral involvement and 83.2±7.2 in patients with tibial involvement. However, this difference was not statistically significant (P=0.13). The mean TESS was 87.3±8.1 in patients with femoral involvement and 86.2±7.5 in patients with tibial involvement. This difference, too, was not statistically significant (P=0.11).

Postoperative Complications and Implant Survival

In total, six postoperative complications were recorded in this series.

Four patients had postoperative complications that did not need prosthesis revision, including one case of wound dehiscence in the tibial reconstruction group (type 1, Henderson failure), one case of periprosthetic fracture in the tibial reconstruction group (type 3, Henderson failure), and two cases of acute infection (type 4, Henderson failure), one in the tibial and one in the femoral reconstruction group. Wound dehiscence was managed with debridement and re-suturing. The periprosthetic fracture was fixed with a locking plate. Acute infections were managed with the exchange of polyethylene liner, debridement, and three days of intravenous antibiotic injection, followed by six weeks of oral antibiotic therapy.

In the last follow-up, 21 of 23 patients (90.5%) had the megaprosthesis in place, while revision was performed in two patients (9.5%). The first revision was due to aseptic loosening (type 2, Henderson failure) in a patient with femoral reconstruction that occurred 36 months after the index surgery. The other revision was due to the delayed periprosthetic infection (type 4, Henderson failure) in a patient with tibial reconstruction that occurred six months after index surgery. Accordingly, the two-year survival of the prosthesis was 95.7% and 90%, respectively [Figure 4].

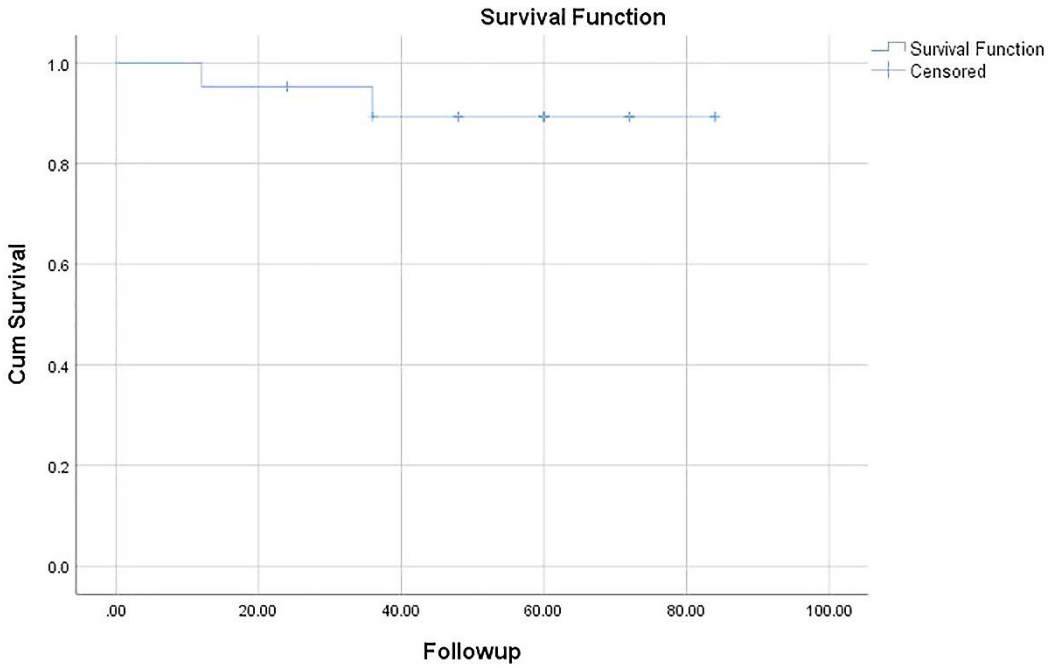

Figure 4. Kaplan-Meier curve showing the survival of megaprosthetic reconstruction for the salvage of a failed primary osteoarticular reconstruction

Aseptic loosening was managed with a larger-diameter femoral stem. Periprosthetic infection was managed with an antibiotic-loaded bone cement spacer for the two-stage revision of infected implants. These patients retained the

revised megaprosthesis in place until the last follow-up, with no other complications. The postoperative complications are demonstrated in more detail in [Table 2].

Table 2. Surgical complications following the endoprosthetic reconstruction performed for the salvage of a failed primary allograft reconstruction

Failure type	Proximal tibia (n=13)	Distal femur (n=8)	Total (n=21)
Mechanical failure			
• Soft tissue failure	1 (7.7)	0	1 (4.8)
• Aseptic loosening	0	1 (12.5)	1 (4.8)
• Structural failure	1 (7.7)	0	1 (4.8)
Non-mechanical failure			
• Infection	2 (15.4)	1 (12.5)	3 (14.2)
• Tumor progression	0	0	0
Total	4 (30.8)	2 (25)	6 (28.6)

Data are presented as numbers (%)

Discussion

Following the introduction of chemotherapy and the dramatic increase in patients' survival, more focus is now placed on the improvement of patients' functional outcomes and reducing surgical complications.[15-17] In this study, we evaluated the functional outcomes, complications, and survival of the megaprosthesis in the salvage of a failed osteoarticular allograft around the knee. The limb length discrepancy was corrected by almost 86% following the substitution of the osteoarticular allograft with a megaprosthesis. The mean MSTS score and TESS were good to excellent in all patients. ,In total6 (28.6%) postoperative complications were recorded in this series, two of which (9.5%) required a revision. Accordingly, the two- and five-year survival of the prosthesis was 95.7% and 90%, respectively.

The outcomes of the megaprosthetic reconstruction of a failed osteoarticular allograft have been reported in a small number of earlier studies. Wang et al. reported the outcomes of megaprosthetic reconstruction in 20 patients following the failure of osteoarticular allograft reconstruction around the knees (n=17) and shoulders (n=3). At a mean follow-up of 77 months, they reported a mean MSTS score of 76%, ranging from 60% to 93.3%.[6] Foo et al. reported the outcomes of megaprosthetic reconstruction for the salvage of a failed allograft in 10 patients. Most of the lesions (n=8) were located in the femur diaphysis or tibia diaphysis, and an intercalary allograft was used in the initial reconstruction. Only two osteoarticular allografts were used in their study. The mean MSTS score of their patients following the megaprosthetic reconstruction was 77.7%, ranging from 60% to 90%.[5] Verbeek et al. compared the results of three salvage procedures, including total joint arthroplasty (n=41), allograft-prosthesis composite (n=14), and megaprosthetic reconstruction (n=16), in patients who experienced DJD following the limb reconstruction with osteoarticular allograft. However, the functional outcomes of the patients were not reported in their study.[4] In the present study, the mean MSTS score of the patients was 83.6% (range: 66.7-93.3), which was slightly superior to that reported earlier. We believe that this better function could be attributed to the use of the trevira tube in the reconstruction of the proximal tibia, which improved the active extension of the knee.[9]

In the present study, 19 of 21 patients (90.5%) retained the prosthesis until the last follow-up. Accordingly, the two- and five-year survival of the prosthesis was 91% and 83%, respectively. In the study of Wang et al., 16 of 20 patients (80%) had a successful megaprosthetic reconstruction. The predicted 5-, 10-, and 15-year survivals of the prosthesis were 92%, 55%, and 28%, respectively.[6] At a mean follow-up of 62.8 months, there was one megaprosthesis failure (10%) in the study of Foo et al., resulting in a mean prosthesis survival of 56.9 months (range: 16-132).[5] In the study of Verbeek et al., only three out of 16 patients (18.7%) who underwent megaprosthetic reconstruction for the salvage of osteoarticular allograft retained the prosthesis until the last follow-up.[4] The present study, in line with the majority of earlier studies, shows a favorable survival rate of almost 90% for megaprosthetic reconstruction as a salvage procedure for osteoarticular reconstruction.

Despite the appropriate survival of the prosthesis, the rate of postoperative complications following the megaprosthetic reconstruction of a failed osteoarticular allograft seems to be high. Wang et al. reported five postoperative complications in 20 patients (25%), including two aseptic loosenings, two infections, and one instability.[6] Foo et al. reported five surgical complications (50%), including one ascetic loosening, one hypoesthesia in the radial nerve distribution, one patellar fracture, one periprosthetic fracture, and one popliteal artery laceration.[5] In the study of Verbeek et al., 13 patients faced complications, all of which failed. Aseptic loosening and infection were the most common types of failure.[4] In the present study, six of 21 patients (28.6%) had postoperative complications. Similar to earlier reports, aseptic loosening and infection were the most frequent postoperative complications.

Zeegen et al. evaluated the survival rate of megaprosthesis in 141 patients at early follow-up. In total, 13 prosthesis failures were recorded in their study, yielding an overall prosthesis survival rate of 91%. The three- and five-year survival rates were 88% and 76%, respectively. The limb function was good to excellent in 74% of patients. The conversion of failed allografts to megaprosthesis showed a trend toward a higher failure rate. However, in the multivariate analysis, it was not an independent predictor of failure.[18] While we only included patients with the conversion of failed allografts to megaprosthesis in the present study, Zeegen et al. used megaprosthesis as the primary salvage method. Interestingly, our study showed a similar survival rate compared to up-front megaprosthesis. However, future comparative studies are required to shed more light on the survival of megaprosthesis as a primary or secondary salvage procedure.

Due to the limited number of similar articles in the literature, the discussion of the present study was largely focused on comparing the results of the current study to procedures or even in the same region of the body. This makes the interpretation and deduction difficult, as a comparison between shoulder and knee endoprostheses may not necessarily be relatable. This inconsistency also remains to be resolved in future investigations.

The present study was not without limitations. The main limitation of this study was the small number of patients. The other main limitation of the study was its retrospective design. Moreover, the study was biased by two main sources. The first source of bias was section bias, as not all of the patients during the study period were treated with megaprosthesis reconstruction. The second source of bias was transfer bias, as two patients were lost to follow-up, and these patients may have had complications. The retrospective design did not allow the evaluation of the functional improvement by comparing the preoperative and postoperative measures. The absence of a control group could be regarded as the other limitation of the study. In addition, the follow-up period of the study was short, and the results should be interpreted in the shadow of this limitation.

Conclusion

A megaprosthesis is a viable option for the salvage of a failed osteoarticular allograft reconstruction around the knee. It provides acceptable knee function and is associated with a low rate of failure, at least in mid-term follow-up. In addition, the limb length discrepancy could be partially corrected with megaprosthetic reconstruction. However, longer follow-up of the patients is necessary for investigating the long-term outcomes and survival of this procedure.

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Khodamorad Jamshidi MD [1]
Wael Ammar MD [1]
Khalil Kargar Shooroki MD [1]
Alireza Mirzaei MD [1]

1 Bone and Joint Reconstruction Research Center, Department of Orthopedics, School of Medicine, Iran University of Medical Sciences, Tehran, Iran

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