ABSTRACT

Modular megaprostheses can be used to reconstruct large osseous defects. They have historically utilized polymethylmethacrylate (PMMA) cement for fixation to host bone. Newer designs incorporating stems that utilize cementless bone-ingrowth technology have become available. We performed a retrospective review of all patients treated at our institutions who have undergone endoprosthetic reconstruction of the proximal femur, distal femur and proximal tibial utilizing cementless fixation. The primary outcome was considered to be loosening or reoperation. Thirty-eight cementless modular megaprostheses were implanted as a subset of endoprostheses used for reconstruction from 2002 through 2007. The decision to use cementless implants was made by the primary surgeon based upon patient age, diagnosis, prognosis, bone quality, and surgeon experience. 23 distal femur, 13 proximal tibia and 2 proximal femur prostheses were implanted. Kaplan Meier estimated implant survival was 88% at 4 years. Three patients developed loosening of their prosthesis that required revision. There were no periprosthetic fractures or cases of implant breakage in our study. We demonstrate good short-term outcome of cementless fixation for tumor endoprostheses with a relatively low complication rate that is similar to previously reported results of contemporary cemented implants.

LEVEL OF EVIDENCE

Level IV

INTRODUCTION

Modular endoprosthesis can be used to reconstruct bone defects resulting from a tumor resection, a metastatic lesion, failed internal fixation or nonunion, or failed total hip or knee arthroplasty [9,11,23]. Other techniques available include osteoarticular allografts and allograft prosthetic composites, however long-term results with these techniques have been less predictable [4,13,18,22,29]. Most current prosthesis designs rely upon polymethylmethacrylate bone cement for fixation to the host bone [7]. Early cementless designs had a high rate of failure related to stem breakage and loosening [6,12]. Never cementless designs have become available and we have begun to use these stems in a select group of patients treated with modular endoprosthetic reconstruction.

Most implanted modular endoprostheses rely upon polymethylmethacrylate cement for fixation [7]. The experience of the arthroplasty community with cemented femoral and tibial components has been positive, with very low revision rates [25]. The long-term durability of cemented modular endoprostheses has not been as reliable, with revision rates of up to 69% at 10-years [26]. The most common mode of failure leading to revision surgery is aseptic loosening, which has been reported to account for up to 44% of revisions of modular endoprostheses [2,3,5,8,26,28,30]. This high rate of failure, and aseptic loosening in particular, may be due to the unique demands of reconstructing large osseous defects. Aseptic loosening can be the result of macrophage mediated osteolysis stimulated by particular wear debris or of mechanical failure of the implant-bone interface [21]. In addition, the length of the prosthesis increases the mechanical stress borne by the bone-cement or bone-implant interface [27]. Implants with larger bone resections, and therefore longer implants, have been shown to have a higher rate of failure [17,27]. Other potential
mechanisms of failure of modular endoprostheses include infection, periprosthetic fracture, and implant breakage [2,12]. In the case of proximal femoral replacement, hip dislocation and recurrent instability are unique modes of failure [20].

In an attempt to increase the strength of the implant-bone interface, and to create a more durable bond, cementless designs have become available. Cementless stems have the advantage of allowing bone-ingrowth and therefore a dynamic bond that can respond over time to the stresses placed upon it [16]. Bone ingrowth, however, is dependent upon numerous mechanical and biologic factors. While the experience of the arthroplasty community has been positive, the effects of radiation and chemotherapy as well as the unique problems associated with oncology patients upon bone ingrowth into cementless stems is poorly understood.

Early cementless stem designs have had a high failure rate related to stem breakage [6,12]. Osteolysis and aseptic loosening also led to failure in up to 27% of patients [19]. These results were based upon the use of stems designed and implanted during the 1980s. Newer designs have recently become available, and the short-term results of these contemporary prostheses have not been reported to our knowledge. At our institution we have used cementless stems in the reconstruction of large osseous defects of the lower extremity in 37 patients. The goal of our study is to define our short-term results with this technique.

**MATERIALS AND METHODS**

We performed a retrospective review of all consecutive patients who underwent endoprosthetic reconstruction of the proximal femur, distal femur and proximal tibial utilizing cementless fixation at our institution from January 2002 through December of 2007. Patients treated with modular endoprosthetic reconstruction were identified through use of our electronic orthopaedic oncology database as well as billing records. All patients treated with cementless fixation and modular endoprosthetic reconstruction of large osseous defects were included in the study. 37 patients were identified, no patients were excluded. Prior to the study, approval was obtained from our institution’s Investigational Review Board (IRB).

The population included in this study represents a portion of the total number of modular endoprosthesis used in the treatment of large osseous defects at our institution. Currently, we utilize both cemented and cementless prostheses as well as allografts and allograft prosthetic composites as part of our clinical practice. The decision to utilize a cementless modular megaprosthesis is made by the operating surgeon, is multifactorial, and includes patient age, perceived bone quality, diagnosis, prognosis, and the use of adjuvant therapies including radiation and chemotherapy.

In all cases the implants used were the Global Modular Replacement System (GMRS, Stryker, Kalamazoo, MI) (Fig. 1). Following resection of the tumor or removal of the previous failed implant, the diaphyseal canal was prepared. The bone end was cut perpendicular to its long axis, leaving a clean and even surface. In most instances a prophylactic circlarge wire was placed around the end of the bone to prevent fracture. The canal was then prepared by sequential reaming until good cortical chatter was obtained. A stem was then selected of the same diameter as the final reamer. In all cases the short straight stem (127mm) was used. A press-fit was then achieved by impacting the stem into the canal.

Data was gathered through review of the electronic and physical patient records and radiographs. All radiographs were interpreted by a single observer (MJW). Information regarding patient age, sex, diagnosis, previous surgery or reconstruction, type and location of implant, adjuvant therapy such as chemotherapy or radiation, post-operative complications and re-operations, loosening and implant failure were documented. Stage was assigned to malignant tumors based upon the Musculoskeletal Tumor Society (MSTS) staging system [10]. The Social Security Death Index (SSDI) was used to confirm mortality.

The primary outcome was considered to be implant failure; this was defined as failure leading to re-operation. Secondary outcome variables included loosening, patient survival and deep infection. Loosening was defined as implant subsidence or a contiguous radiolucent line on plain radiographs around the entire perimeter of the cementless stem. Deep infection included any infection that required operative debridement or any patient with positive cultures following joint aspiration.

Data was compiled and statistical analysis was performed using Microsoft Excel (Microsoft, Redmond, WA) and Sigma Stat 3.5 (Systat, San Jose CA). Kaplan-Meier survival curves were constructed to demonstrate implant longevity and overall patient survival. The Fisher exact test was used to determine if history of a previous reconstructive surgery, perioperative chemotherapy, age, sex, diagnosis of malignancy, or anatomic location were associated with implant failure. Statistical significance was defined as a p ≤ 0.05.
37 patients were implanted with 38 cementless modular endoprosthetic stems (Table 1). Mean follow-up was 23 months (+/- 15 months). One patient underwent reconstruction utilizing both distal femoral and proximal tibial components. Median patient age at the time of surgery was 38 (range 9-81). Seventy percent of patients were male. Eighty-four percent of patients underwent reconstruction following resection of a malignant tumor. Twenty-two distal femoral, 12 proximal tibial, 2 proximal femoral, and 1 combination of distal femur and proximal tibia stems were implanted (Table 2). Sixty-five percent of patients underwent primary reconstruction following a tumor resection, while 45% had had a previous reconstructive procedure that was being revised for implant or allograft failure.

In the cohort of 37 patients there were 3 failures that required revision yielding a Kaplan Meier estimated implant survival of 89% at 4-years (Fig. 2). There were 2 cases of septic loosening and 1 case of failure of bone ingrowth that led to revision. There were no periprosthetic fractures, or direct implant failures or breakage in our series.

The Fisher exact test demonstrated that a previous reconstructive procedure (p = 1.0), male gender (p = 0.21), perioperative chemotherapy (p = 1.0), age greater than 37 (p = 0.23), diagnosis of a malignancy (p = 1.0), and anatomic location (p = 1.0) were not found to predict failure. Kaplan Meier estimated patient survival was 76% at 4-years (figure 3).

### Table 1. Patient characteristics and principle surgical indications for endoprosthetic reconstruction.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median Age</td>
<td>38 (range 9-81)</td>
</tr>
<tr>
<td>Male Sex</td>
<td>70%</td>
</tr>
<tr>
<td>Right Side</td>
<td>54%</td>
</tr>
<tr>
<td>Malignant Tumor</td>
<td>31</td>
</tr>
<tr>
<td>Osteosarcoma</td>
<td>22</td>
</tr>
<tr>
<td>Chondrosarcoma</td>
<td>3</td>
</tr>
<tr>
<td>Other Primary Bone Sarcoma</td>
<td>4</td>
</tr>
<tr>
<td>Metastatic Carcinoma</td>
<td>2</td>
</tr>
<tr>
<td>Benign Tumor</td>
<td>3</td>
</tr>
<tr>
<td>Giant Cell Tumor of Bone</td>
<td>3</td>
</tr>
<tr>
<td>Failed Reconstructive Procedure</td>
<td>3</td>
</tr>
<tr>
<td>Failed Total Hip Arthroplasty</td>
<td>1</td>
</tr>
<tr>
<td>Failed Total Knee Arthroplasty</td>
<td>1</td>
</tr>
<tr>
<td>Tibial Nonunion Following ORIF</td>
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</tr>
</tbody>
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### Table 2. Anatomic location of prosthetic reconstruction and cementless stem sizes.

<table>
<thead>
<tr>
<th>Location of Prosthesis</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Proximal Femur</td>
<td>2</td>
</tr>
<tr>
<td>Distal Femur</td>
<td>22</td>
</tr>
<tr>
<td>Proximal Tibia</td>
<td>12</td>
</tr>
<tr>
<td>Distal Femur and Proximal Tibia</td>
<td>1</td>
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<table>
<thead>
<tr>
<th>Tibial Stem Diameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>11mm</td>
<td>3</td>
</tr>
<tr>
<td>12mm</td>
<td>2</td>
</tr>
<tr>
<td>13mm</td>
<td>2</td>
</tr>
<tr>
<td>14mm</td>
<td>1</td>
</tr>
<tr>
<td>15mm</td>
<td>3</td>
</tr>
<tr>
<td>16mm</td>
<td>2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Femoral Stem Diameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>11mm</td>
<td>2</td>
</tr>
<tr>
<td>12mm</td>
<td>3</td>
</tr>
<tr>
<td>13mm</td>
<td>6</td>
</tr>
<tr>
<td>14mm</td>
<td>5</td>
</tr>
<tr>
<td>15mm</td>
<td>4</td>
</tr>
<tr>
<td>16mm</td>
<td>3</td>
</tr>
<tr>
<td>17mm</td>
<td>1</td>
</tr>
<tr>
<td>18mm</td>
<td>1</td>
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</table>
eventual failure. When large bone defects are reconstructed, 
micromotion that occurs to the cement mantle may accu-
for implant fixation. However, the cement is inert and any 
reliance upon bone growth, healing, or other biologic factors 
cements are formed immediately and there is no 
and filling in the porous bone surface. The bone-cement and 
match to imperfections on the surface of the implant 
ary canal of the host bone. The PMMA cement acts as a grout,
cement is used to fix a smooth or fluted stem into the medul-
ponents to be well placed without signs of loosening. The 
complication. Initial radiographs revealed the components 
the bone implant interface. At 3-1/2 years she 
Diagnosis of osteosarcoma. B. Initial 
phylactic circlage cable has been placed around to cut end of the femur 
undergoing radiation treatment.
Zeegan et al. in a recent review of cemented modular 
ogeneration of cementless modular endoprosthesis from one of our institutions, reported an 88% 
with a cementless megaprosthesis from the diaphyseal bone, which may result in a weak bone–cement interface [24]. Other potential mechanisms of failure include 
breakage [12,19]. In our series there were no direct implant 
implant-bone interface. Our study was not designed to study 
process and may affect the overall strength and quality of the 
impacted into the medullary canal of the host 
Cementless prostheses have a porous or grit blasted stem 
that is tightly impacted into the medullary canal of the host 
Bone. Initial fixation is dependent upon friction between the 
implant and the bone. As the bone heals, it grows onto or into 
the interstices of the rough surface of the implant, creating a 
durable biologic bond between the prosthesis and the host bone 
[16]. As the prosthesis transmits loads through this interface 
to the host bone, any micro-damage that occurs to the bridging 
bone can be healed and remodeled. However, stable bone in-
growth is dependent upon numerous biological and mechanical 
variables. If bone ingrowth fails to occur, early loosening and 
failure can result. Similarly to cemented implants, cementless 
implants are also susceptible to osteolysis from particulate wear 
debris, infection and periprosthetic fracture [16].
While the experience with cementless fixation in the 
arthroplasty literature has been generally positive, the effects 
of adjuvant therapy on the biologic response of the host bone 
to cementless implants in sarcoma or cancer patients is un-
known. Chemotherapy and radiation likely retard the healing 
process and may affect the overall strength and quality of the 
implant-bone interface. Our study was not designed to study 
the effect of chemotherapy and we have avoided using cement-
less stems in patients undergoing radiation treatment.
Zeeghan et al. in a recent review of cemented modular 
megaprosthesis from one of our institutions, reported an 88% 
and 76% survivorship at 3 and 5-years, respectively [30]. The patients studied in this series were treated by the same operat-
ing surgeons as the cementless implants studied in this series 
and had similar outcomes. Similar results have been reported 
by numerous other authors, with a 3-year implant survival of 
82-91% [1,14,15,17,26]. Our results with cementless pros-
theses are similar to these short-term results with cemented 
implants.
Earlier generations of cementless modular endoprosthesis had an unacceptably high failure rate due to implant 
breakage [12,19]. In our series there were no direct implant 
failures. This may reflect advances in component design, met-
allurgy, and manufacturing processes.
This study has a number of limitations. It is a small ret-
rospective case series with a relatively short period of follow-up. However, it appears modular megaprostheses appear to have a 
promising role in the treatment of large osseous defects of the 
lower extremity and their use may be appropriate in a select 
group of patients.
The optimal patient population for treatment with both 
cemented and cementless stem fixation remains unclear. There is likely a subset of patients that may not benefit from 
the use of cementless implants. Further study and long-term 
findings may yield more information allowing specific recom-
mendations to be made on which patient groups are most 
appropriate for cementless fixation.

Figure 4. A. Initial radiographs reveal an aggressive appearing radiolucent mass 
of the left distal femur. Biopsy confirmed the diagnosis of osteosarcoma. B. Initial 
post-operative radiographs following resection of the distal femur and reconstruc-
tion with a distal femoral replacement fixed to the host bone with a cementless 
stem. C. At 3-years post-op, there has now been remodeling of the distal femur with 
hypertrophy of the cortical bone around the cementless stem. There is no radio-
graphic evidence of loosening.

DISCUSSION
The use of cemented and cementless stems both have a 
number of advantages and disadvantages. In the case of a 
cemented prosthesis, polymethylmethacrylate (PMMA) bone 
cement is used to fix a smooth or fluted stem into the medul-
ary canal of the host bone. The PMMA cement acts as a grout, 
conforming to imperfections on the surface of the implant 
and filling in the porous bone surface. The bone-cement and 
cement-implant bonds are formed immediately and there is no 
reliance upon bone growth, healing, or other biologic factors 
for implant fixation. However, the cement is inert and any 
micro-damage that occurs to the cement mantle may accumu-
late over time and can lead to loosening of the implant and 
eventual failure. When large bone defects are reconstructed,
References


