Revision Total Knee Arthroplasty Using Metaphyseal Sleeves at Short-term Follow-up

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Abstract

The treatment of bone loss in revision total knee arthroplasty (TKA) has involved using revision implants in association with cement, augments, particulate, and structural allograft. Newer metaphyseal augments were introduced to allow for metaphyseal fixation of the prosthesis while managing significant bone loss. The purpose of the current study was to evaluate the outcome of revision TKA using metaphyseal sleeves. The authors prospectively followed 96 knees that underwent revision TKA with metaphyseal sleeves. Eighty-three knees met the minimum 2-year criteria for follow-up. Thirty-six sleeves were used in femoral revisions and 83 sleeves were used in tibial revisions. The defects were classified according to the Anderson Orthopaedic Research Institute classification. Femoral defects were classified as type I in 4 knees, type IIb in 25 knees, and type III in 7 knees. Tibial defects were classified as type I in 9 knees, type IIa in 1 knee, type IIb in 68 knees, and type III in 5 knees. The patients were followed for an average of 2.4 years (range, 2.0-3.7 years). Mean Knee Society function score improved from 47.9 to 61.1 points. Mean Short Form 36 physical score improved from 43.3 to 56.3 points. Mean Western Ontario and McMaster Universities Arthritis Index improved from 55.3 to 25.9 points. None of the implants demonstrated progressive radiolucent lines around the metaphyseal sleeves. At final follow-up, only 2 (2.7%) tibial components required revision for aseptic loosening. At short-term follow-up, revision TKA with metaphyseal sleeves provided reliable fixation. This is especially encouraging given the severe nature of bone loss in the majority of patients in whom a metaphyseal sleeve was used. Long-term follow-up is needed to demonstrate the true effectiveness of these devices.

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The number of revision total knee arthroplasty (TKA) procedures performed per year is expected to rise from 38,300 in 2005 to 268,300 by the year 2030.1 In the United States, the most common type of revision TKA involves revision of all components.2 The method of reconstruction used for revision TKA depends on the remaining bone stock, integrity of the ligaments, and ability to balance the flexion and extension gaps. The Anderson Orthopaedic Research Institute (AORI) classification provides a useful tool for classifying and predicting the method of reconstruction of bony defects associated with revision TKA.3 Type I defects involve an intact metaphyseal rim and joint line with bone defects of less than 1 cm. These defects can be reconstructed with cement, morselized allograft, or metal augments. Type II defects involve significant cancellous bone loss with a relatively intact metaphyseal rim and require joint line restoration. Type II defects are stratified into type IIa and type IIb. Type IIa defects involve 1 condyle or side of the tibial plateau, whereas type IIb defects involve both condyles or both sides of the tibial plateau. Type II defects can be reconstructed with metal augments, impaction grafting, structural allograft, metaphyseal sleeves, or porous metal cones. Type III defects involve large metaphyseal rim defects with significant cancellous bone loss and can be reconstructed with impaction grafting, structural allograft, metaphyseal sleeves, porous metal cones, composite allograft, or so-called megaprostheses. The use of cement, metal augments, morselized allograft, structural allograft, impaction grafting, and porous metal cones has been previously reported with short- to midterm follow-up.4–16

Metaphyseal-filling tantalum cones and sleeves are hypothesized to help restore the joint line and provide implant stability in large bony defects by providing a surface for fixation in the metaphysis, allowing surgeons to avoid excess bone resection, and sharing intramedullary loading forces. These implants are 2 distinct technologies with different implantation techniques and philosophies. Multiple recent studies have demonstrated favorable short-term outcomes using tantalum cones.4,6,8,9,11 However, the clinical results of metaphyseal sleeves are relatively unknown. The use of metaphyseal sleeves in 30 hinged revision TKAs with mid-term follow-up was reported by Jones et al,10 with no mechanical failures in the series. Alexander et al15 recently reported a smaller series of 30 tibial metaphyseal sleeves with no failures at short-term follow-up. Metaphyseal sleeves were recently introduced for use with a modular, mobile-bearing knee revision system (P.F.C. Sigma Knee Revision System; DePuy, Warsaw, Indiana). The current study represents the only report, to the authors’ knowledge, of the short-term results of revision TKA with both femoral and tibial metaphyseal sleeves using both nonhinged and hinged designs.

**Materials and Methods**

Institutional review board approval was obtained from the authors’ institution for this study. Ninety-six consecutive revision TKAs using metaphyseal sleeves for tibial and/or femoral bone loss were performed by the senior author (M.A.) between January 2007 and June 2010. Perioperative data were prospectively collected on all patients. Seven patients were lost to follow-up, and 6 patients died prior to reaching 2-year follow-up. The 83 remaining knees (79 patients, 119 sleeves) composed the study cohort. Average duration of follow-up was 2.4 years (range, 2.0 to 3.7 years).

At the time of surgery, average patient age was 63.5 years and average body mass index was 33 kg/m². There were 29 males and 50 females. The indications for revision included aseptic loosening (51 knees), second-stage reimplantation for periprosthetic infection (20 knees), instability (6 knees), periprosthetic fracture (4 knees), and stiffness (2 knees). A modular, mobile-bearing, posterior-stabilized P.F.C. Sigma Knee Revision System (Figure 1) was used in 73 knees, and 10 knees were reconstructed using an S-ROM Noiles hinged prosthesis (DePuy; Figure 2).

Bone defects were classified using the AORI classification.1 Bone loss was evaluated using preoperative radiographs by 2 orthopedic surgeons (A.O., F.O.) not involved in the care of the patients. Metaphyseal sleeves were used in 36 femoral and 83 tibial revisions. Femoral defects were classified as type I in 4 knees, type
Ilb in 25 knees, and type III in 7 knees. Tibial defects were classified as type I in 9 knees, type IIa in 1 knee, type IIb in 68 knees, and type III in 5 knees. Patients were evaluated preoperatively and at each postoperative visit using the Short Form 36 (SF-36), Western Ontario and McMaster Universities Arthritis Index (WOMAC), and functional Knee Society Score (KSS). Postoperative radiographic assessment was performed by 2 high-volume revision joint arthroplasty surgeons (A.O., F.O.) not involved in the care of the patients, based on the Knee Society Total Knee Arthroplasty Roentgenographic Evaluation.\(^1\) Disputes were resolved using review by a third joint arthroplasty surgeon. Only 1 case required review by a third surgeon to confirm evidence of radiographic loosening. Interobserver reliability analysis was performed using the kappa statistic to determine consistency in interpretation of loosening on postoperative radiographs. Interobserver reliability was found to be kappa=0.926 (P<.001; 95% confidence interval, 0.783 to 1.000). Minimum 1-year radiographic follow-up was unavailable for 8 of 83 knees, which were excluded from radiographic analysis.

**RESULTS**

**Clinical Outcome**

Mean Knee Society function score improved from 47.9 (range, 5 to 100) preoperatively to 61.1 (range, 0 to 100; P<.001) postoperatively. Mean SF-36 physical score improved from 43.3 (range, 12 to 75) preoperatively to 56.3 (range, 11 to 89; P<.001) postoperatively, and mean SF-36 mental score improved from 61.8 (range, 17 to 93) preoperatively to 69.4 (range, 22 to 96; P=.024) postoperatively. Mean WOMAC improved from 55.3 (range, 23 to 98) preoperatively to 25.9 (range, 0 to 88; P<.001) postoperatively.

**Radiographic Outcome**

Postoperative anteroposterior radiographs were reviewed at last follow-up. Average tibiofemoral alignment was 4.3° valgus (range, 0° to 8.5°). Average femoral component alignment in the coronal plane was 4.6° valgus (range, 2° to 6.5°) in the entire cohort of patients and 4.5° valgus (range, 2° to 6.5°) in the cohort that had a femoral sleeve. In the patients with femoral metaphyseal sleeves, there were no outliers in femoral component coronal alignment (greater than 9° or less than 2° valgus from the anatomic axis). Average tibial component alignment in the coronal plane was 0.2° varus (range, 3.0° varus to 3.2° valgus). One tibial component was considered an outlier (greater than 3° from neutral mechanical axis). Progressive radiolucent lines around the metaphyseal sleeve were not seen in any of the 29 knees with femoral sleeves nor any of the 75 knees with tibial sleeves for which 1-year postoperative films were available. Progressive radiolucent lines were seen around the femoral stem in 2 knees with femoral sleeves (2 of 29 knees with femoral sleeves) and around the femoral stem in 3 knees without femoral sleeves (3 of 46 knees without femoral sleeves). Progressive radiolucent lines were seen around the tibial stem in 7 knees with tibial sleeves (7 of 75 knees). No evidence of subsidence was seen in any knee.

**Reoperation**

Fourteen (16.9%) knees required reoperation after revision TKA with metaphyseal sleeves (Table). Two (2.4%) patients developed aseptic loosening of the tibial metaphyseal sleeve 2 years postoperatively. Another patient underwent isolated femoral component revision TKA for aseptic loosening (no femoral sleeve). Six (7.2%) knees developed periprosthetic joint infection. Of these 6 knees, 3 underwent 2-stage exchange, 2 underwent irrigation and debridement, and 1 underwent irrigation and debridement and subsequent above-knee amputation. Five of the 6 knees that developed periprosthetic joint infection following use of a metaphyseal sleeve were reimplantations of 2-stage revisions for infection. The incidence of reinfection following use of the sleeve in reimplantation was 5 (25%) of 20 knees, and incidence of infection in cases performed for aseptic etiologies was 1 (1.6%) of 63 knees. One (1.2%) patient underwent partial patellectomy following a patellar fracture, and the remaining 4 (4.8%) patients required a manipulation under anesthesia.

**DISCUSSION**

This study represents the only report, to the authors’ knowledge, of the short-
Feature Article

The term results of revision TKA with both femoral and tibial metaphyseal sleeves using both nonhinged and hinged designs. There is a paucity of information in the literature regarding the outcomes of specific methods of reconstruction used in revision TKA. The short-term survivorship was 92.8% (77 of 83 knees). Only 2 tibial metaphyseal sleeves (2 [2.4%] of 83) were revised for aseptic loosening. No femoral component with a sleeve required revision for aseptic loosening; therefore, survivorship of sleeves was 98.2% (111 of 113 sleeves not revised for infection). This was despite use in a high percentage of AORI type IIb and III defects (85.9% of femoral and 89.0% of tibial revisions). The authors' short-term results demonstrate favorable implant fixation and survivorship using metaphyseal sleeves in the face of massive bone loss.

The decision to use the sleeve was made at the discretion of the operating surgeon based on quantitative and qualitative aspects of the host bone, constraint of the prosthesis to be used, and comfort with the method of reconstruction. Unfortunately, a specific algorithm for use of these sleeves was not used. The authors acknowledge that cost is one important factor in determining the method of reconstruction and recognize that other options exist for reconstruction of type I defects, including, but not limited to, so-called hybrid metaphyseal fixation with cement and fully cemented implants. The use of a sleeve adds approximately 30% to the cost of each implant. The authors acknowledge that use of these implants should be restricted to cases of severe bone loss where conventional reconstructive methods may not provide reliable long-term fixation. Furthermore, the decision to use a sleeve was based on the need for fixation, but implant positioning was also a factor. The authors acknowledge that use of these implants should be restricted to cases of severe bone loss where conventional reconstructive methods may not provide reliable long-term fixation.

Table

Reoperation Following Revision TKA With Metaphyseal Sleeves

<table>
<thead>
<tr>
<th>Patient No./Sex/Age, y</th>
<th>BMI, kg/m²</th>
<th>Indication for Index Revision</th>
<th>Tibial AORI Type</th>
<th>Femoral AORI Type</th>
<th>Sleeve</th>
<th>Hinge</th>
<th>Indication for Reoperation</th>
<th>Reoperation</th>
<th>Time to Reoperation, mo</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/M/69</td>
<td>35</td>
<td>Aseptic loosening</td>
<td>2b</td>
<td>1</td>
<td>T</td>
<td>1</td>
<td>Infection</td>
<td>Resection TKA and spacer</td>
<td>12</td>
</tr>
<tr>
<td>2/M/55</td>
<td>30</td>
<td>2nd stage</td>
<td>2b</td>
<td>2b</td>
<td>T and F</td>
<td>0</td>
<td>Infection</td>
<td>I&amp;D</td>
<td>4</td>
</tr>
<tr>
<td>3/F/80</td>
<td>26</td>
<td>Instability</td>
<td>2b</td>
<td>2b</td>
<td>T and F</td>
<td>1</td>
<td>Arthrofibrosis</td>
<td>MUA</td>
<td>1</td>
</tr>
<tr>
<td>4/F/47</td>
<td>40</td>
<td>2nd stage</td>
<td>2b</td>
<td>2b</td>
<td>T</td>
<td>0</td>
<td>Infection</td>
<td>I&amp;D</td>
<td>2</td>
</tr>
<tr>
<td>5/F/63</td>
<td>37</td>
<td>2nd stage</td>
<td>2b</td>
<td>2b</td>
<td>T</td>
<td>0</td>
<td>Patellar fracture</td>
<td>Partial patellectomy</td>
<td>4</td>
</tr>
<tr>
<td>6/M/67</td>
<td>33</td>
<td>2nd stage</td>
<td>2b</td>
<td>2b</td>
<td>T</td>
<td>0</td>
<td>Arthrofibrosis</td>
<td>MUA</td>
<td>2</td>
</tr>
<tr>
<td>7/F/59</td>
<td>33</td>
<td>Aseptic loosening</td>
<td>2b</td>
<td>2b</td>
<td>T</td>
<td>0</td>
<td>Aseptic loosening</td>
<td>Isolated femoral component revision</td>
<td>26</td>
</tr>
<tr>
<td>8/F/49</td>
<td>29</td>
<td>Aseptic loosening</td>
<td>1</td>
<td>1</td>
<td>T</td>
<td>0</td>
<td>Arthrofibrosis</td>
<td>MUA</td>
<td>2</td>
</tr>
<tr>
<td>9/M/68</td>
<td>33</td>
<td>Aseptic loosening</td>
<td>2b</td>
<td>2b</td>
<td>T</td>
<td>0</td>
<td>Aseptic loosening</td>
<td>1-stage revision TKA</td>
<td>47</td>
</tr>
<tr>
<td>10/F/69</td>
<td>34</td>
<td>2nd stage</td>
<td>2b</td>
<td>2b</td>
<td>T</td>
<td>0</td>
<td>Infection</td>
<td>Resection TKA and spacer</td>
<td>&lt;1</td>
</tr>
<tr>
<td>11/M/71</td>
<td>35</td>
<td>2nd stage</td>
<td>3</td>
<td>3</td>
<td>T and F</td>
<td>0</td>
<td>Infection</td>
<td>Resection TKA and spacer</td>
<td>2</td>
</tr>
<tr>
<td>12/F/79</td>
<td>31</td>
<td>Aseptic loosening</td>
<td>2b</td>
<td>2b</td>
<td>T</td>
<td>0</td>
<td>Aseptic loosening</td>
<td>1-stage revision TKA</td>
<td>22</td>
</tr>
<tr>
<td>13/F/64</td>
<td>28</td>
<td>2nd stage</td>
<td>2b</td>
<td>2b</td>
<td>T and F</td>
<td>0</td>
<td>Infection</td>
<td>Resection TKA and spacer 1</td>
<td>1</td>
</tr>
<tr>
<td>14/F/49</td>
<td>43</td>
<td>Aseptic loosening</td>
<td>3</td>
<td>2b</td>
<td>T and F</td>
<td>0</td>
<td>Arthrofibrosis</td>
<td>MUA</td>
<td>1</td>
</tr>
</tbody>
</table>

Abbreviations: AORI, Anderson Orthopaedic Research Institute; BMI, body mass index; F, femoral; I&D, irrigation and debridement; M, male; MUA, manipulation under anesthesia; T, tibial; TKA, total knee arthroplasty.

The term results of revision TKA with both femoral and tibial metaphyseal sleeves using both nonhinged and hinged designs. There is a paucity of information in the literature regarding the outcomes of specific methods of reconstruction used in revision TKA. The short-term survivorship was 92.8% (77 of 83 knees). Only 2 tibial metaphyseal sleeves (2 [2.4%] of 83) were revised for aseptic loosening. No femoral component with a sleeve required revision for aseptic loosening; therefore, survivorship of sleeves was 98.2% (111 of 113 sleeves not revised for infection). This was despite use in a high percentage of AORI type IIb and III defects (85.9% of femoral and 89.0% of tibial revisions). The authors' short-term results demonstrate favorable implant fixation and survivorship using metaphyseal sleeves in the face of massive bone loss.

The decision to use the sleeve was made at the discretion of the operating surgeon based on quantitative and qualitative aspects of the host bone, constraint of the prosthesis to be used, and comfort with the method of reconstruction. Unfortunately, a specific algorithm for use of these sleeves was not used. The authors acknowledge that cost is one important factor in determining the method of reconstruction and recognize that other options exist for reconstruction of type I defects, including, but not limited to, so-called hybrid metaphyseal fixation with cement and fully cemented implants. The use of a sleeve adds approximately 30% to the cost of each implant. The authors acknowledge that use of these implants should be restricted to cases of severe bone loss where conventional reconstructive methods may not provide reliable long-term fixation.

Furthermore, the decision to use a sleeve was based on the need for fixation, but implant positioning was also a factor. The authors acknowledge that use of these implants should be restricted to cases of severe bone loss where conventional reconstructive methods may not provide reliable long-term fixation. The authors acknowledge that use of these implants should be restricted to cases of severe bone loss where conventional reconstructive methods may not provide reliable long-term fixation.
an important factor. The sleeves may result in imperfect component positioning, or the bone defect geometry that is present may force the component into a less-than-perfect position. Thus, the surgeon must perform proper preoperative planning and surgical execution to reduce the risk of malpositioning. Use of intraoperative radiographs or fluoroscopy may reduce the chance of malposition.

In the current study, alignment of 1 tibial stem and sleeve component was considered an outlier (greater than 3° outside of neutral mechanical axis). Indication for revision in this case was the second stage of a 2-stage revision for periprosthetic joint infection. The patient had AORI type IIb bone loss in both the tibia and femur, and a tibial sleeve was used during reconstruction. At 3-year follow-up, the patient’s radiographs demonstrated a tibial component in 5° of valgus from neutral mechanical axis and femoral component in 3° of valgus, with an overall mechanical alignment of 8° of valgus. There was no evidence of radiographic loosening and no complications related to component positioning.

In cases of loosening of metaphyseal sleeves requiring re-revision, the difficulty in removing metaphyseal sleeves depends on whether osseointegration has occurred. The vast majority of the explantation procedures either occurred in the acute postoperative period prior to osseointegration or were performed for aseptic loosening, greatly facilitating removal of the sleeves. The senior author has removed several well-fixed sleeves that were not included in this study (they were implanted at an outside institution). Anecdotally, the femoral sleeves have required an anterior cortical window for removal, and the tibial sleeves have been less difficult to remove but have occasionally required a tibial tubercle osteotomy. The amount of bone loss encountered at the time of re-revision depends on multiple variables, including host bone stock, fixation of the components, and the need to create a cortical defect.

There are a few significant limitations to this study. First, each patient presents unique challenges, which may have affected the results. This is a problem inherent to all studies involving revision TKA patients. Second, follow-up time was short (an average of 2.4 years [range, 2.0 to 3.7 years]). Third, the authors were not able to formally assess mechanical alignment because full-length standing radiographs were not available for all patients. Finally, 7 patients were lost to follow-up, 6 died before reaching 2-year follow-up, and an additional 8 had no 1-year radiographs available. The authors found no radiolucencies around the metaphyseal sleeves that they were able to evaluate radiographically (75 knees), and it is possible that 1 or more of the patients without radiographs may have had radiolucencies. However, they were not revised for aseptic loosening at a minimum 2-year follow-up. Despite these limitations, this study’s strengths are that it is the first series, to the authors’ knowledge, to report outcomes of metaphyseal sleeves with this revision implant. Furthermore, the cohort of 83 revision TKAs is a relatively large series.

The results of revision TKA are somewhat unclear given the multiple methods of reconstruction, including the use of cement, metal augments, impaction bone grafting, structural bone graft, metaphyseal sleeves, and porous in-growth components. In addition, prosthesis design factors, such as level of constraint and cemented vs uncemented stems, further add to the variability of reconstructive methods and subsequent reporting of outcomes.

The literature on cement filling of defects in revision TKA is scarce. Dorr et al. recommended bone grafting voids greater than 5 mm rather than filling with cement. Patel et al. reported 79 AORI type II defects treated with metal augments at a mean follow-up of 7 years. The components were cemented in a hybrid fixation fashion. The survivorship of the components at 11 years was 92%. Lotke et al. reported the mid-term results of 48 revision knees treated with impaction grafting. They reported no mechanical failures, and all grafts incorporated and remodeled radiographically. The complication rate was 14%, including 2 periprosthetic fractures and 2 infections. The technique was noted to be technically demanding and time consuming. Clatworthy et al. reported 52 revision knees at mid-term follow-up using structural allograft for uncontained defects. Thirteen knees failed, resulting in a 25% failure rate. Allograft survival was 72%. Ghazavi et al. published a series of 30 knees with massive bone defects treated with bulk allograft at an average 50-month follow-up. Two patients failed due to tibial component loosening (in which allograft had been used), 1 patient failed due to graft fracture, and 1 patient failed due to graft nonunion. Bauman et al. reported the Mayo Clinic experience with structural allograft in TKAs. They reported a 22.8% failure rate in a cohort of 70 knees. In contrast to these reports, Engh and Ammeen reported the mid-term results of 46 knees in which structural allograft was used in revision tibial arthroplasty. Four patients in that series required reoperation, but none were directly due to collapse or failure of the allograft.

To the current authors’ knowledge, there are limited data in the literature on results of stepped metaphyseal sleeves. Jones et al. reported a series of 30 knees treated with the S-ROM hinged-knee system with metaphyseal sleeves. They demonstrated no mechanical failures at midterm follow-up of 49 months. Alexander et al. recently reported a smaller series of 30 tibial metaphyseal sleeves with no failures at short-term follow-up. Other porous metal implants have been used with reported short-term success. Long and Scuderi reported a series of 16 cases using tantalum tibial cones in AORI type II and III defects with no mechanical failures at a minimum 2-year follow-up. Meneghini et al. reported a series of 15
porous tantalum cones used for tibial revisions with AORI type II and III defects. All implants showed evidence of osseointegration at an average 34-month follow-up. Howard et al\(^9\) studied a series of 24 porous tantalum cones used for type IIb or greater femoral bone loss during TKA. At a mean 33-month follow-up, no mechanical failures were associated with the use of the cones. Recently, Lachiewicz et al\(^9\) reported outcomes of 33 tantalum cones (9 femoral and 24 tibial) in 27 patients. All cones except for 1 demonstrated evidence of osseointegration at an average 3.3-year follow-up. One knee in their series was revised for femoral cone and component loosening.

**CONCLUSION**

Given the anticipated increase in revision burden in the United States to over 268,000 cases by the year 2030, a reliable method to reconstruct a wide array of bone defects is paramount.\(^2\) The economic effect of these procedures will be substantial, with hospital charges for revision procedures accounting for $4.1 billion and surgical charges reaching $0.34 billion by the year 2015.\(^3\) The outcomes of these procedures will be closely monitored by payers in the future. The anticipated bone loss as assessed by radiographs often underestimates the actual intraoperative bone loss encountered.\(^19\) Therefore, a system to accommodate type I to type III defects would be ideal to allow for reconstruction within a single revision system. The P.F.C. Sigma Knee and S-ROM Noiles hinged knee revision system with metaphyseal sleeves may offer such a method. However, long-term follow-up is required to support the early success seen with the use of these devices.

**REFERENCES**