Metaphyseal Fixation in Revision Total Knee Arthroplasty: Indications and Techniques

Abstract

The need for revision total knee arthroplasty (TKA) is on the rise. Challenges to attaining durable, stable, well-functioning revision TKA include bony deficiency, periarticular osteopenia, deformity, and soft-tissue imbalance. Defect management often requires the use of stems, cement, metal augmentation, or allograft. Recently, there has been interest in obtaining fixation in the metaphyseal region in an attempt to improve construct stability while managing bony deficiency. Often, the metaphyseal bone is well vascularized, which provides an opportunity for additional fixation with cement, allograft, trabecular metal cones, or stepped porous-coated sleeves. Multiple series have documented good survivorship at short-term follow-up with trabecular metal cones and porous-coated sleeves. These newer technologies offer biologic fixation and are useful for treating bony defects that are not easily managed with other methods. Long-term studies are needed to determine the durability of these constructs. Concerns persist regarding stress shielding and difficulty of removal. Familiarity with the rationale and strategies for metaphyseal fixation in revision TKA is a valuable addition to the armamentarium of the revision surgeon.

The number of patients requiring revision total knee arthroplasty (TKA) is projected to increase dramatically.1,2 Increasing numbers of patients are undergoing primary TKA, and at a younger age.3,4 Therefore, more patients will require revision at a younger age, as well. Bony deficiencies are common, and various management strategies have been described.4,8 Effective defect management provides stable, durable reconstruction with well-balanced flexion and extension gaps through restoration of soft-tissue symmetry. The Anderson Orthopaedic Research Institute (AORI) classification of bone defects is useful for guiding revision TKA (Table 1) (Figure 1).

The epiphysis, metaphysis, and diaphysis are the three general anatomic regions in which fixation may be obtained in revision TKA. In the revision setting, reliance on epiphyseal fixation alone results in high rates of mechanical failure.5,6,8 In persons who require revision TKA, the epiphyseal bone is deficient, osteopenic, and likely poorly vascularized; thus, cementation techniques and implants similar to those employed in primary TKA are unreliable. For this reason, the use of stems has become commonplace in revision TKA. Stems unload the epiphyseal fixation by transferring a portion of the stress proximally in the femur and distally in the tibia.4,14
Stems are available for cemented and press-fit implantation techniques. Considerable controversy surrounds the optimal implantation strategy. There are proponents of cemented and press-fit stems, and data are available documenting the efficacy of each strategy.8,10-12,14,15 Cemented stems can be shorter than press-fit stems because they do not need to engage the diaphysis; thus, they can be “cheated” inside the medullary canal without influencing the position of the implant. For example, cemented stems can be useful in situations in which diaphyseal engagement could cause implant malalignment. They also allow delivery of antibiotic cement, and they can provide durable fixation in osteopenic patients with capacious canals. A shorter cemented construct may be an advantage in the patient with a total hip arthroplasty (THA) ipsilateral to a total knee that requires revision. Removal of cemented stems can be difficult, however.

Most press-fit stems have no ingrowth potential because they are not typically covered with an ingrowth surface. However, they do appear to effectively offload articula fixation. Multiple studies have documented excellent survivorship.8,12,13,15 Press-fit stems that engage the diaphysis also assist in obtaining correct limb alignment. Problems with press-fit stems include the need for offset capability when diaphyseal engagement causes implant malposition, as well as iatrogenic fracture and end-of-stem pain.9 To be effective, a press-fit stem must engage the diaphysis. Failure rates of 16% to 29% have been reported for short, metaphyseal-engaging press-fit stems.5,6,10 Thus, relatively long constructs are typically needed.5,6,10

Recently, there has been interest in targeting the metaphyseal area of the distal femur and proximal tibia for

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**Table 1**

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
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<tbody>
<tr>
<td>1</td>
<td>Intact metaphyseal bone. Good cancellous bone at or near a normal joint-line level.</td>
</tr>
<tr>
<td>2</td>
<td>Damaged metaphyseal bone. Loss of cancellous bone that requires cement fill, augments, or small bone grafts to restore a reasonable joint-line level.</td>
</tr>
<tr>
<td>3</td>
<td>Deficient metaphyseal bone. Deficient bone that compromises a major portion of either condyle or plateau; these defects usually require a large structural allograft, a rotating hinged component, or custom component.</td>
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**Figure 1**

construct stability during revision TKA. Typically, the metaphyseal bone is relatively undamaged and well vascularized, which is advantageous for cement interdigitation, noncemented fixation, and allograft incorporation. Additionally, for more severe defects (ie, AORI types 2 and 3), metaphyseal fixation is necessary to achieve construct stability. Metaphyseal fixation may be obtained with cementation, allograft incorporation, or conical metal implants designed to fit the metaphyseal region. Each method has advantages and disadvantages (Table 2).

### Metaphyseal Cementation

Short, fully cemented stems take advantage of metaphyseal fixation, which may allow good cement interdigitation into healthy cancellous bone. This likely contributes to the good long-term survivorship documented in recent studies.5,24

The so-called hybrid stem fixation technique is one of the most common examples of exploiting the metaphysis for additional fixation during revision TKA. The hybrid method uses diaphyseal-engaging press-fit stems with cement applied to the cut bony surfaces and extended a variable amount along the base of the stem to allow interdigitation of cement and healthy metaphyseal bone. This technique addresses the difficulty of fully cemented stem removal because the cement is metaphyseal only and therefore is more readily accessible from the joint. It also addresses concern regarding longer-term fixation with completely noncemented stems because additional axial and rotational forces are likely borne by the metaphyseal cement.

Several published series have documented the efficacy of hybrid fixation, including a recent study that noted 12-year survivorship with no mechanical failure in 98% of cases.15 Several other series have documented similar excellent outcomes with hybrid stem fixation at shorter follow-up. It is prudent, therefore, to obtain some metaphyseal cement fixation when stems are used, whether with a fully cemented short stem or a hybrid technique with a diaphyseal-engaging press-fit stem. Long-term follow-up data support the durability of both strategies (≥10 years).15

### Allograft

Several series have documented the efficacy of using large structural allograft to manage massive periarticular bone loss during revision TKA.16-26 The main concerns include allograft resorption with resulting mechanical failure, technical difficulties in graft sizing and preparation, infection, surgical time, and disease transmission. A recent series documented a concerning rate of mechanical failure resulting from graft resorption.27 Sixty-five patients who underwent revision with structural allograft were followed for a minimum of 5 years; the overall failure rate was 22.8%. The 10-year survivorship of the reconstructions was 75.9%.

Allograft may incorporate into the underlying metaphyseal bone. However, if it resorbs under the tibial tray, for example, the tray can lose mechanical support and fail over time. These procedures require considerable artistry and experience,

<table>
<thead>
<tr>
<th>Method</th>
<th>Advantages</th>
<th>Disadvantages</th>
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<tbody>
<tr>
<td>Structural allograft</td>
<td>Mid- and long-term efficacy</td>
<td>Graft resorption</td>
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<td></td>
<td>Custom fit with intraoperative shaping</td>
<td>Technically demanding</td>
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<td></td>
<td>Biologic interface with host</td>
<td>Time-consuming</td>
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<td></td>
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<td>Disease transmission</td>
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<td></td>
<td></td>
<td>Graft availability</td>
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<tr>
<td>Trabecular metal cones</td>
<td>Short-term data encouraging</td>
<td>Cost</td>
</tr>
<tr>
<td></td>
<td>Variety of shapes and sizes</td>
<td>Difficulty with removal</td>
</tr>
<tr>
<td></td>
<td>Can be shaped intraoperatively for custom fit</td>
<td>Cemented interface to implant</td>
</tr>
<tr>
<td></td>
<td>Trials and instruments available</td>
<td>Irritating to soft tissues</td>
</tr>
<tr>
<td>Metaphyseal stepped</td>
<td>Midterm data encouraging</td>
<td>Cost</td>
</tr>
<tr>
<td>porous-coated sleeves</td>
<td>Efficient, simple</td>
<td>Difficulty with removal</td>
</tr>
<tr>
<td></td>
<td>Can be used as cutting guides</td>
<td>Not compatible with implants from other manufacturers</td>
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<tr>
<td></td>
<td>Instrumented</td>
<td>Not useful for uncontained defects</td>
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and the best results have been reported by surgeons who perform a high volume of revision procedures. With the growing popularity of large metal augmentation in the management of massive defects, it is likely that the use of large structural allografts will decrease. No data comparing large metallic augmentation with structural allograft have been published.

Particulate allografting techniques have also been described. One method involves impaction grafting of cancellous bone chips about an intramedullary (IM) stem and into periprosthetic bone defects followed by full cementation of the component. Wire mesh may be used for uncontained defects. Lotke et al reported no mechanical failures in 42 patients at 2- to 7-year follow-up. White-side described a technique that relies on rim contact of the tibial tray, careful preservation of the soft-tissue envelope, and long, tightly implanted fluted diaphyseal-engaging press-fit stems. In this “rim and stem” method, particulate allograft fills metaphyseal voids, and the well-vascularized metaphyseal bone likely contributes to bony incorporation and remodeling.

Although these techniques do not rely on initial metaphyseal fixation, they deserve mention because they take advantage of a well-vascularized metaphysis by allowing effective incorporation of particulate allograft bone. Proponents of this technique support a noncemented strategy for fixation in revision TKA that is somewhat analogous to the use of extensively coated cylindrical stems in hip revision surgery. The deficient periarticular bone is bypassed, and diaphyseal fixation is obtained. Concerns exist regarding the long-term performance of the modular junction between a well-fixed diaphyseal stem and the femoral or tibial components. Longer-term follow-up studies are necessary.

**Metaphyseal-filling Trabecular Metal Forms**

Porous tantalum Trabecular Metal forms (Zimmer, Warsaw, IN) are commercially available in multiple sizes and geometries. This material has demonstrated predictable bony ingrowth and has been used effectively to manage severe bony deficiencies in the acetabulum during revision THA. Recently, the use of porous tantalum has been expanded to the knee; these preformed cones have been used as an alternative to large structural allograft as well as massive quantities of IM cement, particularly in AORI type 2 and 3 defects.

The major concerns with structural allograft are graft resorption and mechanical failure, along with the considerable time and surgical skill required to obtain good host-allograft interface. However, porous tantalum forms are available in various shapes, sizes, and trials, and bony ingrowth into this material is relatively predictable. The coefficient of friction of porous tantalum is high, allowing for a good scratch fit when it is impacted into remaining bone and good primary implant stability. The revision components are “unitized” to the cone by a cemented interface (Figure 2).

To create a custom fit, porous tantalum can be contoured with a burr, cut, or drilled. Available cones are compatible with most revision implant systems. Contemporary instrumentation and trials can facilitate implantation. Two recently published series have documented good short-term results with these implants for severe tibial bony defects (ie, AORI types 2 and 3). Predictable radiographic ingrowth was noted, and the rate of mechanical failure was low. These excellent results were reported by experienced high-volume revision surgeons. The applicability of the techniques on a larger scale has not been established.

Cost is one major concern with porous tantalum implants. However, it likely compares favorably with the cost and surgical time associated with large structural allograft procurement and preparation. Other concerns include difficulty with removal and long-term interface durability. The long-term durability of the cemented interface between the implant and the trabecular metal is unknown. Additionally, the material may be irritating to surrounding soft tissues because of its high coefficient of friction. Currently, these implants are most useful for massive bony deficiencies of the proximal tibia and distal femur (ie, AORI types 2 and 3).

**Metaphyseal Sleeves**

Instrumented, stepped porous-coated metaphyseal sleeves (DePuy, Warsaw, IN) have been available for more than a decade for revision TKA applications. In theory, when the sleeve is osteointegrated, it carries a portion of the axial load, effectively protecting the epiphysial fixation and improving the rotational stability of the construct more than is possible with a simple fluted cylindrical stem. Additionally, the sleeves can be used as instruments, effectively acting as IM cutting guides. It is common during revision to encounter large osteopenic canals that make IM guides unstable. For example, even if the tibial diaphysis is reamed to endosteal reamer chatter, the enlarged tibial medullary cavity proximally allows the reamer to wobble because of lack of containment, leading to instability with the IM cutting guides. The capacious proximal tibia cannot reliably support an IM cutting jig. Periarticular bony deficiencies can...
make secondary pins useless for cutting block stabilization. The use of metaphyseal sleeves that fill the metaphysis allows stable cutting platforms because sleeves occupy more of the metaphysis than does a tubular reamer or pilot stem. Pinning jigs are unnecessary in the revision setting. Bony cuts can be made by referencing the top of the metaphyseal broach directly, obviating the need for cutting guides. The process is analogous to broaching the proximal femur in noncemented THA. During routine noncemented THA, the femoral canal is reamed and broached to rotational and axial stability, after which calcar planing may be performed. The popularity of instrumented sleeves has been driven by the efficiency of obtaining alignment while managing the defect and by the opportunity to achieve noncemented metaphyseal fixation (Figure 3).

Instrumented sleeves also can be used to manage more severe bony deficiency, similar to that discussed for tantalum cones. The primary difference between trabecular metal cones and metaphyseal sleeves is that the interface of the sleeve with the implant is created via a Morse tapered junction rather than with cement. It has been postulated that a well-osteointegrated sleeve or cone would more effectively resist rotational stresses than a cylindrical stem alone, whether cemented or noncemented. Rotational stress is a particular concern with more constrained implants, such as those with varus-valgus constraint or hinged mechanisms. Jones reported a large series of hinged reconstructions using a press-fit stem and sleeve in both the femur and tibia. Only one modular junction failure occurred. Predictable radiographic osteointegration was noted. Midterm data exist regarding the performance of metaphyseal sleeves in revision TKA. In general, sleeve-based constructs have...
demonstrated good osteointegration and no deterioration of the interfaces over time. However, longer-term follow-up is necessary.

The major concerns with sleeves include difficulty with removal, long-term durability, and epiphyseal stress shielding. Additionally, the junctions between the ingrown metaphyseal sleeves and the articular components must be robust enough to prevent junctional failure over time. Iatrogenic fracture can occur with vigorous sleeve impaction. Unlike trabecular metal cones, the sleeves themselves cannot be customized with a burr to fit defects with unusual geometries. Additionally, sleeves require circumferential containment with enough host bone to allow axial and rotational stability, so they may not be applicable in more severe uncontained defects. There are trabecular metal forms that can be used to manage severe epiphyseal deficiencies without circumferential metaphyseal containment. Because the trabecular metal forms are fixed by adjunctive cement, there is the potential for thermal necrosis of host bone. No early published clinical outcomes have documented this to be problematic.

Summary and Future Directions

The increasing number of patients undergoing TKA and at a younger age presages the need for a greater number of revision TKAs. Current options for revision include metaphyseal cementation, allograft, and metaphyseal-filling trabecular forms. Few long-term outcomes studies are available on the newer techniques. The best results have been reported by surgeons who are experienced in revision TKA.

Improvement in techniques, biomaterials, and indications for noncemented implants likely will lead to noncemented revision TKA. This trend will mirror the evolution that has occurred with revision THA implants and techniques. Broader commercial offerings that target metaphyseal fixation will expand the surgeon’s armamentarium of efficient and effective defect management strategies. Orthobiologic agents, or so-called biologic cements, will likely complement or replace conventional methacrylate fixation techniques. Allograft and metallic augmentation techniques are not mutually exclusive. Familiarity with both strategies and techniques is useful. Well-designed studies are needed to determine whether these new techniques will provide durable reconstructions in these challenging cases.
References

References printed in bold type are those published within the past 5 years.


uncemented acetabular cup in revision total hip arthroplasty: Clinical and radiological results of 60 hips.


