5 Points on
Implant Designs in Revision Total Knee Arthroplasty

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Before 1990, a considerable number of revisions were performed, largely for implant-associated failures, in the first few years after index primary knee arthroplasties.[1,2] Since then, surgeons, manufacturers, and hospitals have collaborated to improve implant designs, techniques, and care guidelines.[3,4] Despite the substantial improvements in designs, which led to implant longevity of more than 15 years in many cases, these devices still have limited life spans. Large studies have estimated that the risk for revision required after primary knee arthroplasty ranges from as low as 5% at 15 years to up to 9% at 10 years.[4,5]

The surgical goals of revision total knee arthroplasty (TKA) are to obtain stable fixation of the prosthesis to host bone, to obtain a stable range of motion compatible with the patient's activities of daily living, and to achieve these goals while using the smallest amount of prosthetic augments and constraint so that the soft tissues may share in load transfer.[6] As prosthetic constraint increases, the soft tissues participate less in load sharing, and increasing stresses are put on the implant–bone interface, which further increases the risk for early implant loosening.[7] Hence, as characteristics of a revision implant become more constrained, there is often a higher rate of aseptic loosening expected.[8]

Controversy remains regarding the ideal implant type for revision TKA. To ensure the success of revision surgery and to reduce the risks for postoperative dissatisfaction, complications, and re-revision, orthopedists must understand the types of revision implant designs available, particularly as each has its own indications and potential complications.

In this article, we review the classification systems used for revision TKA as well as the types of prosthetic designs that can be used: posterior stabilized, nonlinked constrained, rotating hinge, and modular segmental.

1 Classification of bone loss and soft-tissue integrity

To further understand revision TKA, we must consider the complexity level of these cases, particularly by evaluating degree of bone loss and soft-tissue deficiency. The most accepted way to assess bone loss both before and during surgery is to use the AORI (Anderson Orthopaedic Research Institute) classification system.[9] Bone loss can be classified into 3 types: I, in which metaphyseal bone is intact and small bone defects do not compromise component stability; II, in which metaphyseal bone is damaged and cancellous bone loss requires cement fill, augments, or bone graft; and III, in which metaphyseal bone is deficient, and lost bone comprises a major portion of condyle or plateau and occasionally requires bone grafts or custom implants (**Table 1**). These patterns of bone loss are occasionally associated with detachment of the collateral ligament or patellar tendon.

In addition to understanding bone loss in revision TKA, surgeons must be aware of soft-tissue deficiencies (eg, collateral ligaments, extensor mechanism), which also influence type and amount of prosthesis constraint. Specifically, constraint choice depends on amount of bone loss and on the condition of stabilizing tissues, such as the collateral ligaments. Under conditions of minimal bone loss and intact peripheral ligaments, a less constrained device, such as a primary posterior stabilized system, can be considered. When ligaments are present but insufficient, a semiconstrained device is recommended.

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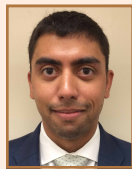
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Table 1. AORI (Anderson Orthopaedic Research Institute) Bone Loss Classification System

Type	Description
I	Metaphyseal bone intact; defects do not compromise stability
II	Metaphyseal bone damage, cancellous bone loss; consider augments/bone graft
III	Metaphyseal bone deficient, major bone loss involving plateau or condyles; consider bone graft or custom implant

Figure 1. Posterior stabilized implant used for AORI (Anderson Orthopaedic Research Institute) type I.

Table 2. Indications for Different Revision Implant Designs

Implant Design	Indications
Posterior stabilized	1. AORI type I—minimal bone loss 2. Incompetent posterior cruciate ligament 3. Adequate collateral ligament balancing 4. Adequate flexion/extension balancing
Nonlinked constrained	1. AORI type II or III—high degree of bone loss 2. Incompetent posterior cruciate ligament 3. Required complete revision of tibial and femoral components 4. Functional loss of collateral ligaments 5. Flexion/extension mismatch 6. Repeated dislocations of posterior stabilized design
Rotating hinge	1. AORI type II or III—high degree of bone loss 2. Severe ligamentous instability
Modular segmental	1. AORI type III—extensive bone loss cannot be treated with allografts or augments 2. Complete ligament disruption or absence 3. Loss of periprosthetic soft tissue 4. Oncologic conditions requiring bony excision 5. Unreconstructible knee fractures 6. Multiple previous revision surgeries

Abbreviation: AORI, Anderson Orthopaedic Research Institute.

In the presence of medial collateral ligament attenuation or complete medial or lateral collateral ligament dysfunction, a fully constrained prosthesis is required.[8] Therefore, amount of bone loss or soft-tissue deficiency often dictates which prosthesis to use.

For radiographic classification, the Knee Society roentgenographic evaluation and scoring system[10] has been implemented to allow for uniform reporting of radiographic results and to ensure adequate preoperative planning and postoperative assessment of component alignment. This system incorporates the evaluation of alignment in the coronal, sagittal, and patellofemoral planes and assesses radiolucency using zones dividing the implant–bone interface into segments to allow for easier classification of areas of lucency. More recently, a modified version of the Knee Society system was constructed.[11] This modification simplifies zone classifications and accommodates more complex revision knee designs and stem extensions.

2 Posterior stabilized designs

Cruciate-retaining prostheses are seldom applicable in the revision TKA setting because of frequent damage to the posterior cruciate ligament, except in the case of simple polyethylene exchanges or, potentially, revisions of failed unicompartmental TKAs. Thus, posterior stabilized designs are the first-line choice for revision TKA (**Figure 1**). These prostheses are indicated only when the posterior cruciate ligament is incompetent and in the setting of adequate flexion and extension and medial and lateral collateral ligament balancing.

However, studies have shown that posterior stabilized TKAs have a limited role in revision TKAs, as the amount of ligamentous and bony damage is often underestimated in these patients, and use of a primary implant in a revision setting often requires additional augments, all of which may have contributed to the high failure rate. Thus, this design should be used only when the patient has adequate bone stock (AORI type I) and collateral ligament tension. This situation further emphasizes the importance of performing intraoperative testing for ligamentous balance and bone deficit evaluation in order to determine the most appropriate implant (**Table 2**).

3 Nonlinked constrained designs

Nonlinked constrained (condylar constrained) designs are the devices most commonly used for revision TKAs (>50% of revision knees). These prostheses provide increased articular constraint, which is required in patients with persistent instability, despite appropriate soft-tissue balancing. Increased articular constraint allows for more knee stability by providing progressive varus-valgus, coronal,

and rotational stability with the aid of taller and wider tibial posts.[12] Specifically, these implants incorporate a tibial post that fits closely between the femoral condyles, allowing for less motion compared with a standard posterior stabilized design.[12]

In addition, these designs may be used with augments, stems, and allografts when bone loss is more substantial. In particular, stem extensions allow for load distribution to the diaphyseal regions of the tibia and femur and thereby aid in reducing the increased stress at the bone–implant interface, which is a common concern with these implants. However, these extensions cost more, require intramedullary invasion, and are associated with higher rates of leg and thigh pain.[12]

These prostheses are often implicated in cases involving a high degree of bone loss (eg, AORI type II or III). They are ideally used in cases in which complete revision of both tibial and femoral components is needed and are indicated in cases of incompetent posterior cruciate ligament, partial functional loss of medial or lateral collateral ligaments, or flexion-extension mismatch.[13] Furthermore, use of a constrained prosthesis is recommended in the setting of varus or valgus instability, or repeated dislocations of a posterior stabilized design (Table 2).

Ten-year survivorship ranges from 85% to 96%, but this is substantially lower than the 95% to 96% for condylar constrained prostheses used in primary TKAs.[14-17] Moreover, the large discrepancy between survivorship of primary TKA and revision TKA with a constrained prosthesis further affirms that the complexity of revision surgery, rather than the prosthesis used, may have more deleterious effects on outcomes. However, surgeons must be aware that increased constraint leads to increased stress on the prosthetic interfaces with associated aseptic loosening and early failure, and this continues to be a legitimate concern.

4 Rotating hinge designs

Many patients who undergo revision TKA can be managed with a posterior stabilizing or nonlinked constrained design. However, in patients who present with severe ligamentous instability and bone loss (AORI type II or III), a rotating hinge prostheses, or highly constrained

device, is often recommended (**Figure 2**).[18] By using a rotating mobile-bearing platform, this prosthesis permits axial rotation through a metal-reinforced polyethylene-post articulation in the tibial tray. In addition, it involves use of modular diaphyseal-engaging stems and diaphyseal sleeves, which allow for the bypass of bony defects and areas of bone loss (Table 2).

However, the rigid biomechanics of hinged prostheses is associated with increased risk for aseptic loosening (aseptic 10-year survival, 60%-80%), imparted by the transfer of stresses across the bone. The higher risk for early loosening, osteolysis, and excessive wear—caused by the highly restricted biomechanics of early generations of fixed hinged designs—has led to the development of new devices with mobile mechanics. Prosthetic designs have been improved with an added rotational axis to reduce torsional stress, a patellar resurfacing option, and better stem fixation and patellofemoral kinematics. Overall, these are aimed to improve rates of instability and aseptic loosening, with promising results demonstrated in the literature.

5 Modular segmental arthroplasty designs

Segmental arthroplasty prostheses, which typically are end-of-the-line revision TKA options, are applicable only in cases of extensive bone loss (more than can be treated with allografts or augments; AORI type 3), complete ligamentous disruption/absence, loss of periprosthetic soft tissue, and multiple previous revision procedures (**Figure 3**). Despite the limited indications for these prostheses, they yield quick return to function without graft nonunion or resorption, and they augment ingrowth/ongrowth. Furthermore, the next surgical option could be fusion or amputation. When failures were specifically evaluated for aseptic loosening across 4 studies, the survival rate ranged from 83% to 99.5%, with the most frequent complication being infection (up to 33% in one series).[6,19-21]

The major roles for segmental arthroplasty prostheses in primary TKAs are in the setting of oncologic conditions that require bony excision, or unreconstuctable fractures about the knee. Used after ancillary metastatic disease, these prostheses demonstrate positive results, according to several reports.[22,23] In the setting of revision TKA, however, these prostheses should be used only when other surgical options are unfeasible, given the high risk for infection and the re-revision rates. Currently, revision TKAs with tumor prostheses have a high failure rate (up to 50%) because of the extensive surgery and the lack of bony and soft-tissue support (Table 2).

Figure 2. Left rotating hinge implant used for AORI (Anderson Orthopaedic Research Institute) type II or III.

Figure 3. Modular segmental distal femoral replacement used for AORI (Anderson Orthopaedic Research Institute) type III.

Conclusion

Orthopedists performing revision TKAs must consider bone stock and remaining ligament stability. In particular, they should choose implants for least constraint and adequate knee stability, as these are essential in minimizing the stresses on the implant–bone interface. Ultimately, functional outcomes, survivorship, and postoperative satisfaction determine the success of these designs. However, predictors of outcomes of revision surgery are often multifactorial, and surgeons must also consider procedure complexity and patient-specific characteristics.

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