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Contemporary bone loss options: Rebuild, reinforce, and augment

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ABSTRACT

Bone loss is commonly encountered during revision total knee arthroplasty (TKA). Small defects can be adequately managed with cement filling (with or without screws), modular prosthetic augments, and morselized allograft. For larger defects, cancellous impaction grafting and structural allografts have traditionally been utilized. More recently, highly porous tantalum cones and titanium sleeves have been designed to achieve axial and rotational stability in the metaphysis and subsequent biologic fixation. Sleeves are linked to one type of prosthesis, whereas cones are unlinked and can be used with any implant design. Multiple studies have demonstrated excellent survivorship and radiographic osseointegration at mid-term follow-up. This article provides a review of contemporary methods of bone loss management with a focus on highly porous metals and an emphasis on the authors' preferred method for managing the severe bone loss in revision TKA.

1. Introduction

Bone loss is frequently encountered during revision total knee arthroplasty (TKA). Based on the 2012 Australian Orthopaedic Association registry data, the two most common causes for revision TKA are loosening/osteolysis (30%) and infection (22%), with both diagnoses being associated with varying degrees of femoral and tibial bone loss [1]. Reconstitution of lost bone with autograft, allograft, or prosthetic material is needed to provide a stable platform for a well-fixed, well-aligned, and stable revision TKA [2].

2. Evaluation

A thorough history and physical examination, laboratory analysis, radiographic investigation, and evaluation of prior operative notes and implant information must be performed prior to considering a revision TKA. Neurovascular examination, previous scars, knee range of motion, soft-tissue status, and ligamentous stability guide surgical management. Laboratory data including C-reactive protein (CRP) and erythrocyte sedimentation rate (ESR) should be performed on every TKA considered for revision to evaluate for infection. If there is any concern for infection, a knee arthrocentesis should be completed. Imaging includes anteroposterior (AP), lateral, and patellar views of the knee, as well as a long-leg standing radiograph to assess overall limb alignment. While plain radiographs are often sufficient, a computerized tomography (CT) scan may help better define the quantity of bone loss preoperatively when significant osteolysis is present [3]. In our practice, CT scans are rarely obtained preoperatively given that intraoperative findings vary after removal of prior components.

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3. Classification

Bone loss in revision TKA is classified according to the Anderson Orthopaedic Research Institute (AORI) [4] description. Type 1 defects have intact and sufficient metaphyseal cancellous bone stock. Type 2A defects have damaged metaphyseal cancellous bone of only one femoral condyle or only one tibial plateau. Type 2B defects have variable amounts of metaphyseal bone loss in both femoral condyles and tibial plateaus. A type 3 defect has bone loss that comprises a major portion of the femoral or tibial metaphysis in both condyles and plateaus and possible damage to the collateral ligament and patella tendon insertions, respectively. While categorizing bone loss on preoperative radiographs is beneficial, a greater degree of bone loss is often found after removal of the components, retained cement, fibrous tissue, and necrotic bone [5].

4. Surgical management

4.1. *Type 1 defects*

Mild, or AORI type 1 defects, include simple cystic lesions around the femoral condyle or proximal tibia and may be easily treated with simple cement fill or morselized cancellous bone graft. For defects between 5 and 10 mm, the structural integrity of the cement mantle can be augmented with screws that are inserted into the condyle or plateau with the screw heads just below the intended level of the implant [6]. This is a cost-effective treatment method that may not have the durability of modular metal augments and should be reserved for lower demand, elderly patients.

4.2. *Type 2 defects*

Type 2 defects have a varying degree of damage to the metaphysis. As such, a host of reconstruction techniques can be utilized based upon the severity of bone loss. These include structural augmentation (autograft, allograft, or prosthetic) and longer stems that bypass the defect and offload the joint line. Type 2A defects, particularly those with peripheral cortical involvement, can be treated with modular metal augments. Lombardi et al. [7] recommended the use of modular augments when >50% of the femoral condyle and/or tibial plateau were compromised with a defect greater than 5 mm in depth. Augments for the tibia come in wedge or block shapes and can fill a defect up to 20 mm. Augments for the distal femur can be placed either distally or posteriorly and are up to 8–10 mm in length, depending on the revision system. Distal femoral augments help reconstitute the joint line and posterior augments help with rotational alignment and improve overall bone–implant contact and stability. Patel et al. [8] reported 92% survivorship in 79 revision TKAs treated with modular metal augments at mean follow-up of 11 years.

Type 2B defects are those that have variable amounts of metaphyseal bone loss in both femoral condyles or both tibial plateaus. They are treated in a similar fashion as described below for type 3 defects.

4.3. *Type 3 defects*

Type 3 bone loss represents the most severe bone loss encountered in revision TKA and involves extensive metaphyseal bone loss with structural impairment of both femoral condyles and/or both medial and lateral tibial compartments. Reconstruction options include metaphyseal structural support in the form of structural allograft, highly porous metaphyseal cones, and stepped titanium sleeves [9–14]. Structural allografts provide a stable reconstruction for large bone defects and may be manually sculpted to reconstitute any type of bone defect. The allograft may be a femoral head, distal femur, or proximal tibia. Ideally, the allograft should be attached directly to host bone to encourage incorporation, and secured with a long cemented stem. However, preparation of structural allografts to fit the native defect can be technically demanding and time consuming [11,14]. In addition, it carries a risk of disease transmission, deep infection, and graft non-union, resorption, fracture, or collapse [14]. In a recent systematic review on structural allografts in revision TKA, a total of 551 bulk allografts were used in 476 revision TKAs at a mid-term follow-up of 5.9 years [15]. The cumulative results demonstrated a 6.5% reoperation rate for loosening or fracture of the graft, a 3.4% rate of aseptic loosening of the prosthesis, and a 5.5% rate of deep infection. In this large cohort of patients with mid-term follow-up, the reduced durability of structural allografts is a cause for concern.

More recently, highly porous metaphyseal cones (Fig. 1) have been introduced as an alternative method to achieve metaphyseal fixation, initial structural support, and long-term biologic fixation through osseointegration [16,17]. Biomechanically, metaphyseal fixation is advantageous to long-term implant durability as enhanced proximal loading leads to increased bone regrowth and ingrowth and minimizes potential stress-shielding that may be seen with diaphyseal engaging press-fit stems [18]. Achieving well-fixed metaphyseal structural support also provides axial and rotational stability closer to the bone–implant interface where the joint reactive forces are greatest. The two main prosthetic options designed for uncemented metaphyseal fixation are highly porous cones and titanium sleeves.

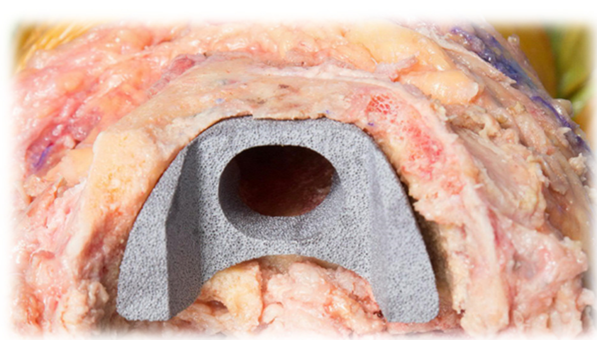

Figure 1 – Intraoperative photograph depicting a type 2B femoral defect treated with a highly porous femoral cone for reconstitution of the metaphysis with bony ingrowth.