

Knee Bony Defects Reconstruction in Revision Total Knee Arthroplasty for Aseptic Loosening

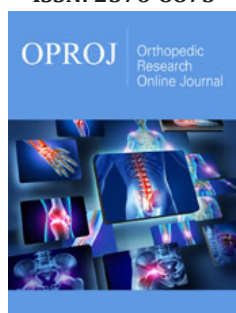
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Abstract

Revision total knee arthroplasty (TKA) is expected to increase owing to increased number of primary knee replacement surgery done annually. Aseptic loosening considered to be one of the commonest indications for revision surgery. One of the common challenges facing the surgeon during revision surgery is how to reconstruct bony defect to obtain optimum component alignment and robust fixation. Careful pre- and intra-operative assessment is crucial and understanding of different reconstruction options side by side with sound implant selection is crucial for successful surgery. Options for bone defect reconstruction include cement with screws, morselized allograft, bulk structural allograft, modular wedges, metal augments, porous metal cones and sleeves.

Keywords: Bony defect; Reconstruction; Revision; Knee arthroplasty

Introduction

Revision total knee arthroplasty (TKA) is expected to increase dramatically owing to increasing number of primary TKA done annually [1]. Although TKA is a cost-effective procedure, revision TKA is considered more costly because of the expected higher rate of complications, prolonged surgical time, greater blood loss, prolonged hospital stays and the need for special implants [2,3]. One of the most important challenges during revision TKA, is how to deal with bone defects with its size variability and different locations, however, several techniques had been developed to compensate for these defects [4]. Soft tissue status (collateral ligaments and extensor mechanism) should be taken into consideration when evaluating the amount of bone defect and deciding how to reconstruct, a systematic approach and full orientation of the implants and reconstruction options are required for effective management of bone loss and to achieve reproducible clinical outcomes [4].

In this review we will discuss the reconstruction options for bone defects in revision TKA after failed primary TKA due to aseptic loosening.

Aetiology of osteolysis and subsequent aseptic loosening

Aseptic loosening can be the result of inadequate initial fixation, mechanical loss of fixation over time, or biologic loss of fixation caused by particle-induced osteolysis around the implant [5]. Wear debris is formed at prosthetic joint articulations, modular interfaces, and non-articulating interfaces remains the major factor limiting the survival of joint implants [6,7]. Subtle progression of tissue destruction around the implant imposes a major challenge, because signs and symptoms may not be clinically apparent until late stages of failure. The basis of periprosthetic tissue destruction, the so-called 'biologic response' to implant debris, is complex. However, this response is the outcome of multiple factors, including physical and biologic components [5,8]. At the core of the biologic response that leads to osteolysis is activation of the receptor activator of nuclear factor- κ B, (RANK)/RANK ligand (RANKL) axis, which is indicated by expression of RANK, RANKL, and osteoprotegerin (OPG) in periprosthetic membranes [9,10]. This activation ends in enhanced osteoclast recruitment and activity adjacent to bone-implant interfaces, leading to osteolysis [11,12].

Patient evaluation

History and clinical examination: A detailed history and physical examination will aid the surgeon in diagnosing the cause of TKA failure, as well as excluding other causes of failure, pain location, character, timing, and duration should be reported of pain. Competency of soft tissue envelop is very crucial to be assessed pre-operatively [4].

Laboratory investigation: These types of investigations mainly to exclude infection, serum erythrocyte sedimentation rate (normal, 20mg/dL) and C reactive protein level (normal, 10mg/dL) should be evaluated, and if elevated, knee aspiration should be done [13].

Radiological assessment: weight-bearing AP, lateral, and skyline radiographs should be done, with the radiographs of the index surgery if possible. The AP and lateral views are helpful for

determine component size, fixation, and the degree of bone loss. The skyline view evaluates patellar component fixation and tracking. Full length extremity AP (hip to knee to ankle) radiographs are helpful in determining the presence of diaphyseal deformities and periarticular hardware, for assessment of the ipsilateral hip joint, and overall limb alignment [14]. MRI and CT have a high sensitivity and specificity for diagnosis of osteolysis around TKA [15]. However, these kinds of imaging are not recommended as a routine owing to its increased cost and radiation exposure. 9 also, lesions can be difficult to identify due to metallic artefact effect [16].

Classification of bone loss in revision TKA

The most used classification system is The Anderson Orthopaedic Research Institute (AORI) classification [17] (Figure 1) (that represents the evolution of the Engh classification [18]) which categorizes bone defects into three principle types.

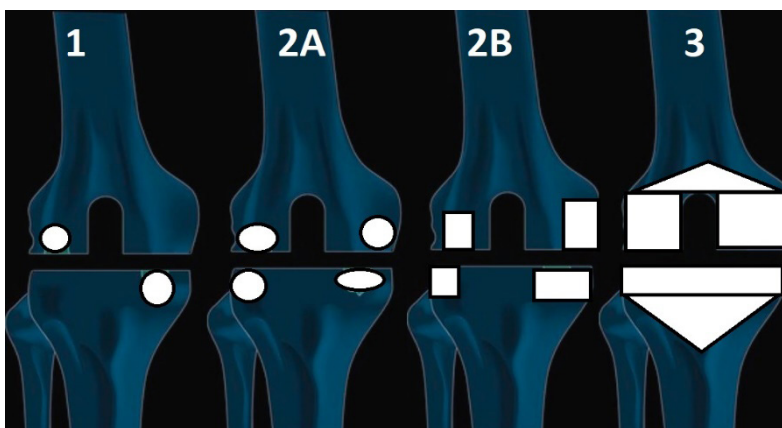


Figure 1: AORI classification for bone defect in revision TKA.

Type 1 defects when the metaphyseal bone is intact with cancellous cavity defects without cortical defects. When considerable metaphyseal bone loss, it is considered as Type 2 defects, which can be further divided into: type 2A defects affecting only one femoral condyle or tibial plateau, and type 2B defects when both femoral condyles and tibial plateaus are involved. Type 3 defects if there is severe bone loss affecting major portion of the femoral condyle or tibial plateau which may violate ligaments or tendon insertions.

Re-classification of defect type usually needed intra-operative after implant and cement removal to compensate for bone lost during implant extraction. Engh argued: "the surgeon should anticipate the worst scenario, because often the defects turn out to be more severe than predicted from radiographs" [19].

Reconstruction options

Many factors should be taken into consideration when deciding if the patient can be treated non-surgically with close monitoring and follow up in combination with pharmacological options, or the osteolysis and component loosening is evident and necessitate revision, in this situation the decision should be made regarding

revision of one component or the whole prosthesis and how to reconstruct the bony and soft tissue defect if present.

Non-surgical

Apart from optimum fixation and improvement of the prosthetic component during primary surgery, Pharmacological strategies to prevent aseptic loosening to target the cellular components (osteoblasts and osteoclasts) that contribute to implant failure had been advocated [20].

Bisphosphonates (BPs), most commonly used in treatment of osteoporosis, had been shown to prevent early migration in TKR [21] and are associated with lower revision risk in epidemiological studies [22,23].

Human clinical trials showed the efficacy of BPs in reducing particle-induced osteolysis over the first post-operative year of implanting cemented and cement less hip and knee replacement prostheses, the results were even better and more durable when treatment was started early after surgery and continued for over 6 months [24,25].

A meta-analysis of 14 randomized controlled trials employing BPs after joint arthroplasty found that the protective effect of these

drugs, may continue till the mid-term follow-up after surgery and for 18 to 70 months after drug discontinuation. BPs [26].

Giving the fact that a biological reaction to wear particles is involved in the process of osteolysis and subsequent implant loosening involving the activation of the receptor activator of nuclear factor- κ B, and (RANK)/RANK ligand (RANKL) axis [27], using substance which blocks this biological reaction thought to help in prevention of early osteolysis progression in solidly fixed implants [28].

Denosumab which is another antiresorptive, a human monoclonal antibody (IgG2) which has a high binding affinity and specificity to RANKL, which may lead to preventing activation of its receptor, RANK, on the surface of osteoclast precursors and osteoclasts, with subsequent prevention of osteoclast formation and reducing its function and survival with resulting reduction in both cortical and cancellous bone resorption [29].

In a randomized, double blind placebo-controlled trial by Ledin et al. [28] where they studied 50 patients where they had TKA for osteoarthritis with an injection of either Denosumab (60mg) or placebo 1 day after knee replacement surgery and again after 6 months. To detect component motion, radiostereometric analysis (RSA) was performed postoperatively and after 6, 12, and 24 months after surgery. They showed that there was significantly less migration of the component in the Denosumab group compared to the control group both at 12 and 24 months. They concluded that using Denosumab after TKA will help to decrease late loosening.

Surgical

AORI type I: Impaction grafting of morselized allograft as it was originally described in revision total hip arthroplasty was modified for use in revision TKA to restore bone stock, especially in younger patients in whom future revision surgeries are expected [30]. In a study of 42 revision TKAs performed with morselized graft, Lotke et al. [31] found no evidence of failure at an average 3.8 years follow up, with an adequate graft incorporation and remodelling in all

cases. In a report of 14 patients with failed impaction grafting in a revision TKA, Whiteside et al. [32] showed that biopsy specimens of the allografts had bone maturation and trabecular formation in all samples taken from areas of impacted bone graft.

Another option is to reconstruct using cement with screws is indicated. If the defect is a mild contained or uncontained more than 5mm but less than 10mm [33]. The screws will reinforce the cement, but screws heads should be slightly below the implant [34]. The screws will help to distribute the load away from the joint line and cement bone interface. Some authors [35] recommend the use of bone graft if the cement mantle below the tibial plateau is greater than 5mm thick. Primary implants with the cement to fill the defects was suggested by Toms et al. [36] & Ritter et al. [37] as an ideal method to treat these defects if it is less than 5mm in breadth and depth [36,37].

AORI type II: Type 2 defect management involving the use of revision implant and the following surgical techniques.

A. Bone grafts: Impaction bone grafting as mentioned with type 1 defects can be used, when the defect is contained with bone loss more than 10mm or a mild uncontained defect less than 50% of tibial plateau/condyles, this technique will help to restore bone stock [30]. It is not recommended if a cortical or uncontained defect are encountered, as the cortical rim is important for the stability of the tibial tray [38].

B. Modular metal augments (Figure 2): Metal augments are available to reconstruct either femoral or tibial defects, which comes in different shapes and sizes either cemented or cementless [39]. It is advisable to use augments in uncontained bone defects with moderate and severe bone loss >50% and >5mm of the femoral condyle and/or tibial plateau [40]. The size of the metal augments correlates to the size of the prostheses, and should compensate for the size of the defect using different thicknesses and angles. It will be assembled to the tibial or femoral components using screws. The choice between using a wedge or block should be according to the best option closely filling the defect [41].

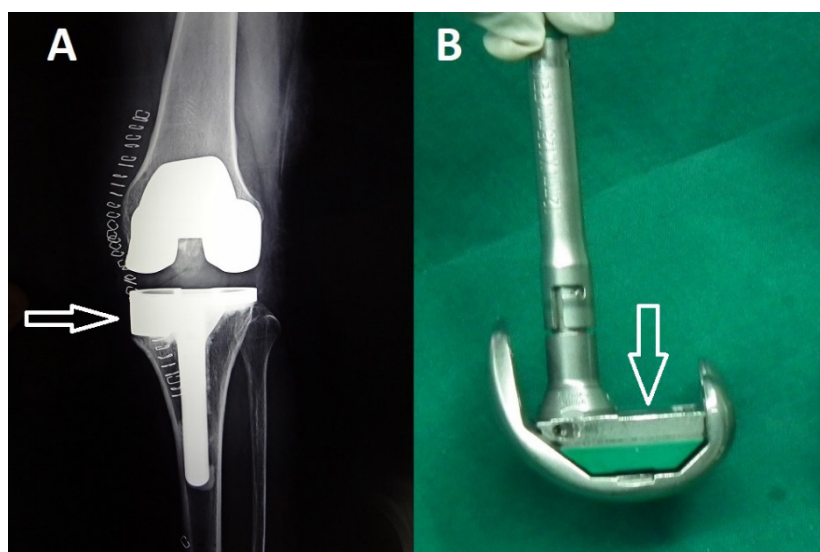


Figure 2: Metal augments, A: Medial tibial, B: Distal femoral.

The advantages of using metal augments are the possibility to modify the implant intra-operatively with no worry of collapse, exact filling of bone defects which had been geometrically shaped with instruments, they provide stable support and transfer loading forces to the bone [42]. Modern metal augments preserve a high volumetric porosity for bone ingrowth, with low modulus of elasticity and high frictional characteristics, making this metal favourable for biologic fixation [43]. However, it carries some disadvantage, the risk of fretting and corrosion still an issue [41].

Also, the difference in elasticity between metal and bone may lead to stress shielding which may increase potential bone loss [42]. Another major problem is the limitation of the height of the augment only up to 20mm, which may not be suitable for larger defects [42]. Some reports showed that augmented prostheses with metal wedge showed mechanical superiority to cement alone or cement with screws in terms of resisting movement when loaded [44]. Some authors advice that better results when graft is combined with augments, with a failure of 48% when the augments were used alone compared to only 19.2% when graft and augments were used in combination [45]. The success rates in the literature using these augments range from 84% to 98% good or excellent results [41,46].

AORI type III: Constrained or Megaprotheses with stems, is always the choice for such defects. Among the options to reconstruct bony defects in this type, structural allografting, cones or metaphyseal sleeves.

A. Structural allograft: It will be preferred to provide a stable and durable reconstruction of large or segmental bone deficiency in patients with a life expectancy greater than ten years, also suitable when the defects are segmental but not greater than 15mm for the

femur and 20-45mm for the tibiam [47].

Different types of allografts can be used, but femoral heads, distal femoral segments, and proximal tibial segments are commonly used, but it requires a vital host bone, when incorporated into the host bone, it may provide some stress protection to the implant [48]. Its usage carries some risks, as bacterial and viral disease transmission, immune response, resorption, and fatigue fracture [42]. Several reports believe showed a bulk allograft survival between 72% and 86% at eight to ten years of follow up [49]. In Eng.'s opinion the survivorship after eight years is 92% when a bulk allograft was used [50]. While, Bauman et al. [51] in their series showed limits when using this technique [51].

B. Cones (Figure 3): Filling metaphyseal defects with cones provides a base of mechanical support for the implant, with the high variability of sizes and shapes allows a good adaptability of these modules to the cavitory metaphyseal bony defects [52]. Its reported success may be attributed to the highly porous nature of the material which allows early osteointegration [53]. It also has a low modulus of elasticity of which facilitates more load transfer and preservation of bone stock [54]. It is of great hep in reconstructing large cavitory defects in which a reliable cortical shell in the face of a metaphyseal endosteal bone defect is present; when used with offset stems when necessary, may eliminate the need for bone grafting or allografting [41]. On the femoral side, using distal femoral cones help to re-establish the metaphyseal-diaphyseal junction and create a stable platform for the femoral component; which will provide structural and mechanical support [42]. After 2 years follow up, Lachiewicz et al. [55] found that tantalum cones were fully integrated. In the Mayo Clinic experience, tantalum cones were found to have osteointegrated in 100 % of tibial [55] and femoral cases [53].



Figure 3: Trabecular metal cone.

C. Metaphyseal sleeves (Figure 4): Femoral sleeves are indicated in patients where there is a metaphyseal deficiency, if there is a limited bony support for the femoral component and if there is difficulty controlling the rotation of the femoral implant, femoral sleeves may also be beneficial when there is significant posterior femoral condyle bone loss, as they can add rotational stability of the implant [42]. Unlike tantalum cones, where the

implant is fixed to the cone by cement, metaphyseal sleeves are fixed to the implant with a morse taper [4]. The most common complication from the use of metaphyseal sleeves is fracture when broaching the sleeves in the tibia or the femur [56]. A prospective study examined outcomes of 83 revision TKAs with metaphyseal femoral and tibial sleeves at a minimum 2-year follow up [57]. None of the knees demonstrated progressive radiolucent lines around the

metaphyseal sleeves. At final follow-up, two tibial sleeves (2.7%) required revision for aseptic loosening.

Conclusion

Bony defect reconstruction during revision TKA is challenging. Early detection of osteolysis with the possibility of pharmacological treatment before frank implant loosening may have a role. A detailed patient history, physical examination, and radiographic

assessment are essential for surgical planning. Care should be taken when removing the implants to avoid further iatrogenic bone loss. Different options and technique are present to reconstruct tibial and femoral bony defect encountered during revision surgery. Careful selection between these options and judicious implant use will help to achieve a reproducible radiological and clinical outcomes.

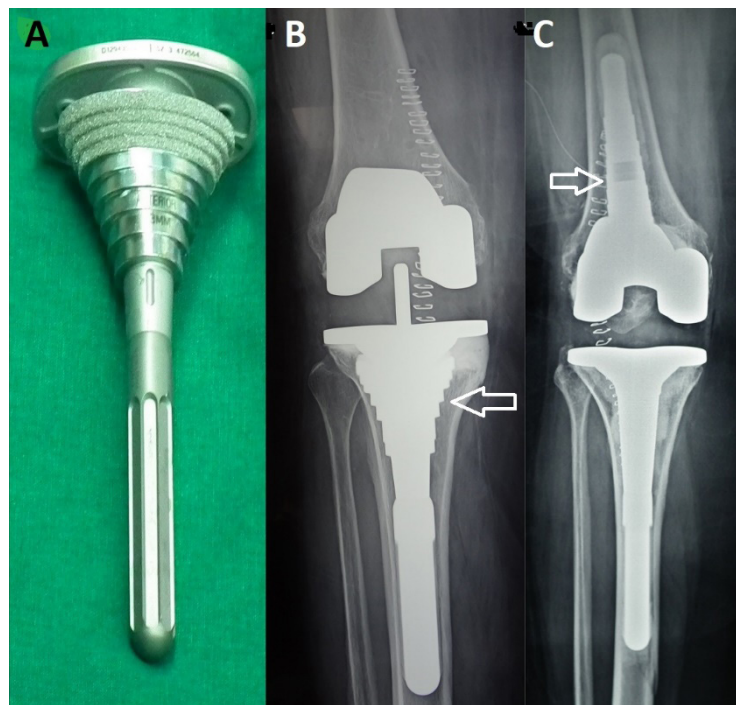


Figure 4: Sleeves, A&B: Tibial, C: Femoral.

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