42 Management of Bone Defects in Revision Total Knee Arthroplasty: Concept of Sleeves

Amar S. Ranawat and Samuel Rodriguez

42.1 Introduction

The volume of primary total knee arthroplasty (TKA) procedures performed annually is on the rise [1, 2]. Subsequently, the number of patients requiring revision knee arthroplasty (RKA) is increasing as well [3]. During RKA, surgeons are frequently challenged by bone loss. Boney deficiency hinders obtaining stable and durable fixation along with appropriate alignment and gap balancing. An assortment of methods for reconstruction are available [4]. Improved surgical techniques and implant design have resulted in outstanding TKA success rates [5], but unfortunately, RKA is unavoidable in a cluster of patients. RKA outcomes are suboptimal when compared to primary TKA, both in terms of functional improvement and in terms of survivorship. Thus, a systematic approach is necessary. Thorough preoperative evaluation and meticulous preoperative planning are crucial to providing reproducible and reliable outcomes.

Modes of failure for TKA include periprosthetic infection, aseptic loosening, instability, prosthetic fracture, polyethylene wear and osteolysis, stiffness, patellar dislocation, and periprosthetic fracture. Regardless of the indication for revision surgery, bone defects are frequently encountered either due to the mode of failure or during implant removal. Engh et al. developed the Anderson Orthopaedic Research Institute (AORI) classification for bone loss in RKA (Table 42.1), the most commonly used system to assess bone loss [6]. Metaphyseal sleeve use is indicated for defects classified as AORI type 2 or greater.

Understanding the concept of zonal fixation provides the foundation for preoperative planning and the framework on where and how fixation can be achieved to provide a stable construct. The distal femur and proximal tibia may be divided into three anatomical zones: zone 1, the epiphysis or joint line; zone 2, the metaphysis; and zone 3, the diaphysis [7]. In the majority of RKA cases, epiphyseal bone is likely to be missing, sclerotic, and poorly vascularized, thereby compromising zone 1 fixation. The metaphysis provides a large contact surface area, abundant trabecular bone, and rich vascularity—an ideal environment to achieve initial as well as long-lasting stability and fixation. Moreover, its proximity to the articulating surface aids in joint line restoration as well as permitting the use of shorter stems and minimizing the need for offset.

Recently, metal augmentation with metaphyseal sleeves has become desirable as a means to achieve durable fixation. Sleeves can manage defects of a variety of shapes and sizes in a dura-

A. S. Ranawat (✉)
Hospital for Special Surgery, New York, NY, USA

Weill Cornell Medical College, New York, NY, USA

NewYork-Presbyterian Hospital, New York, NY, USA
e-mail: ranawatamar@hss.edu

S. Rodriguez
Hospital for Special Surgery, New York, NY, USA

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Table 42.1 AORI bone loss classification

Defect (femoral and tibial)	Description	Metaphyseal bone	Collateral ligaments	Implant stability
Type I	Minor contained cancellous bone loss	Intact	Intact	Uncompromised
Type II				
A	Moderate to severe cortico-cancellous defect affecting one condyle/plateau	Damaged	Intact	Femur: Joint line elevation and reduced condylar profile
B	Moderate-to-severe cortico-cancellous defect affecting both condyles/plateaus	Damaged	Intact	Tibia: Implant is at or below the tip of the fibular head
Type III	Severe segmental and cavitary defect; may compromise extensor mechanism	Deficient	Compromised	Marked component migration

ble and efficient manner. Accompanying metaphyseal sleeves with diaphyseal stems, either short-cemented or long-uncemented, is up to surgeon preference. Distal fixation may reduce micromotion in the bone–implant interface optimizing conditions for bone ingrowth. Recently, some authors have reported mixed results using stemless metaphyseal sleeve constructs although a greater follow-up period is necessary [8, 9].

While there is no consensus for bone loss management, a variety of techniques to replace deficient bone stock have been described, each taking advantage of different fixation zones. In this chapter, we will focus on the indications, techniques, advantages, and limitations on the use of femoral and/or tibial metaphyseal sleeves in revision knee arthroplasty.

42.2 Preoperative Evaluation and Planning

Investigating the indication for revision arthroplasty is of upmost importance, patients will likely complain of pain, instability, and/or loss of function. Obtaining a detailed history and physical examination is essential. Patient history should include etiology for index procedure, surgeries on the affected knee preceding primary TKA, subsequent procedures on ipsilateral knee, and possible inciting events such as trauma and dental procedures. Infection should always be pondered as a cause of failure. Physical examination of the knee and adjacent joints is required.

Preoperative imaging should include but not limited to weight-bearing anteroposterior (AP), lateral, sunrise, and 45° posteroanterior (PA) radiographs (Fig. 42.1). Full-length standing AP radiographs are useful in assessing diaphyseal deformity and mechanical limb alignment. Advanced imaging is not routinely encouraged to diminish costs and exposure to radiation. Preoperative imaging is indicative of the degree of bone loss and frequently underestimating bone loss due to implant removal. Consequently, final evaluation is performed intraoperatively.

42.3 Surgical Technique

Indications: Bone defect classified as AORI type 2a or greater

Aims:

1. Restoration of mechanical and rotational alignment
2. Restoration of joint line
3. Obtain coronal and sagittal plane balancing
4. Augmentation of bone loss
5. Achieve stable and durable fixation
6. Bone conservation for future revisions

Following appropriate exposure and implant removal, definitive assessment and classification

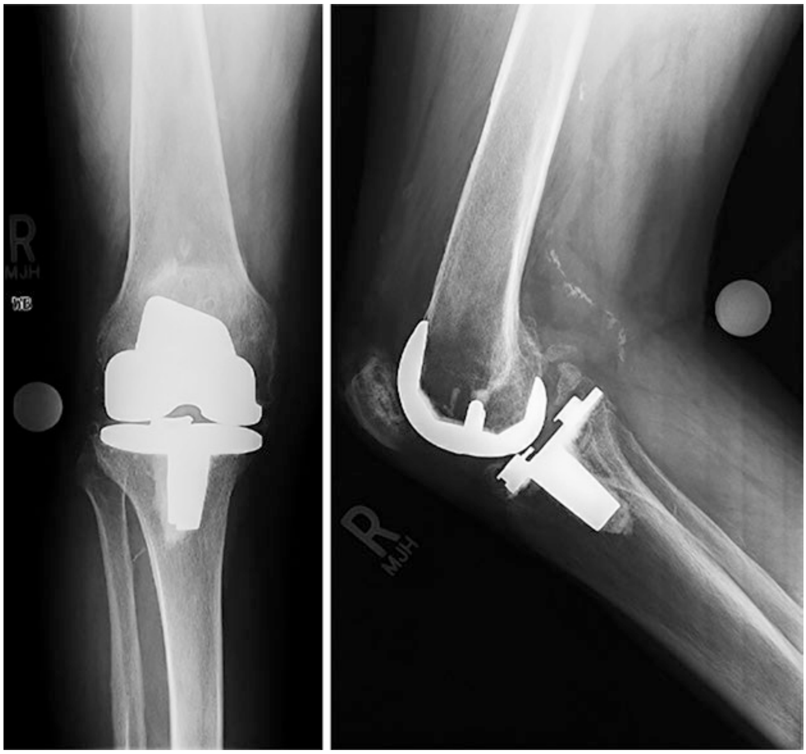

Fig. 42.1 Preoperative standing AP and lateral X-rays of a knee revised for aseptic loosening and osteolysis

of the bone defect are made based on the AORI classification. Begin by straight reaming the tibial medullary canal in a sequential fashion until diaphyseal endosteal contact is obtained, this will determine stem diameter. Next, taper ream to the desired level of proximal tibia resection. Using the predetermined stem diameter assemble the broaching construct, the broach is asymmetrical in the AP dimension and appropriately labeled to identify the anterior aspect, starting with the smallest size possible. Afterward, perform sequential increase in broach size until axial and rotational stability is obtained. While broaching, it is essential to properly align (rotational & coronal) the broach as translation of forces may result in iatrogenic fractures. Thus, maintaining broach alignment is crucial. In the presence of sclerotic bone, the broach may deviate away from the sclerotic side; the senior author recommends the use of a high-speed burr to remove sclerotic bone. The top of the metaphyseal broach may be used as reference, perpendicular to the mechanical axis of the tibia, to freshen the proximal tibial bone cuts only in absence of meta-diaphyseal deformity. If so, the use of an extramedullary guide is recommended.

For trialing purposes, assemble the tibial tray with the appropriate sleeve and stem. The metaphyseal sleeve engages the stem via a morse tapered junction and permits 20° of rotational freedom allowing congruency with tibial base plate rotation. Consequently, tibial tray rotation is based on optimal bone coverage while avoiding overhang.

Before femoral preparation estimate flexion-extension gaps using the spacer blocks, taking into account femoral component size and the need for either distal or posterior augments. Similar to the tibial preparation, a sequentially ream and then broach is employed. Commence straight reaming followed by tapered reaming until the canal is opened to allow for broaching. Pay close attention as the femoral broach is asymmetrical, mediolaterally, and the narrow side must point medially. While broaching verify rotational stability and joint line restoration. With the femoral broach seated, an intramedullary guide is placed. Attach the distal femoral cutting jig at 5° valgus for freshening of distal femoral cuts. Next, couple the AP cutting jig onto the guide and ensure rotation is parallel to the resurfaced proximal tibia since a symmetrical flexion gap and patellofemoral alignment are dependent on the AP cut. Finish femoral preparation by completing the chamfer and notch cuts. Now perform trial reduction to assess joint line level, stability, and flexion-extension gap symmetry. Some cases may demand a more constrained construct if stability and gap imbalances persist after a combination of soft-tissue releases, augmentation and adjustment of the femoro-tibial components, and polyethylene size is performed.

Remove trial components meticulously to preserve the rotation of the sleeves relative to the femoral and tibial components as final component rotation should accurately match. Cementing the femoral component and tibial base plate is recommended unless the remaining bone rim is too narrow for cement interdigitation. Apply doughy-phase cement to the distal femur and proximal tibia as well as to the prosthetic components while avoiding cement to settle into the metaphysis, as metaphyseal cementation may prevent sleeve osseointegration. Ensure proper rotational alignment before impaction to avoid fracture. With a trial polyethylene insert, hold the knee in extension until the cement cures. Perform final trialing and stability assessment after cement hardening, followed by final polyethylene insertion and wound closure (Fig. 42.2).

Surgical Pearls:

1. Do not broach only
2. Ream as much as possible
3. Use high-speed burr to remove sclerotic bone
4. Broach gently ensuring proper rotational alignment

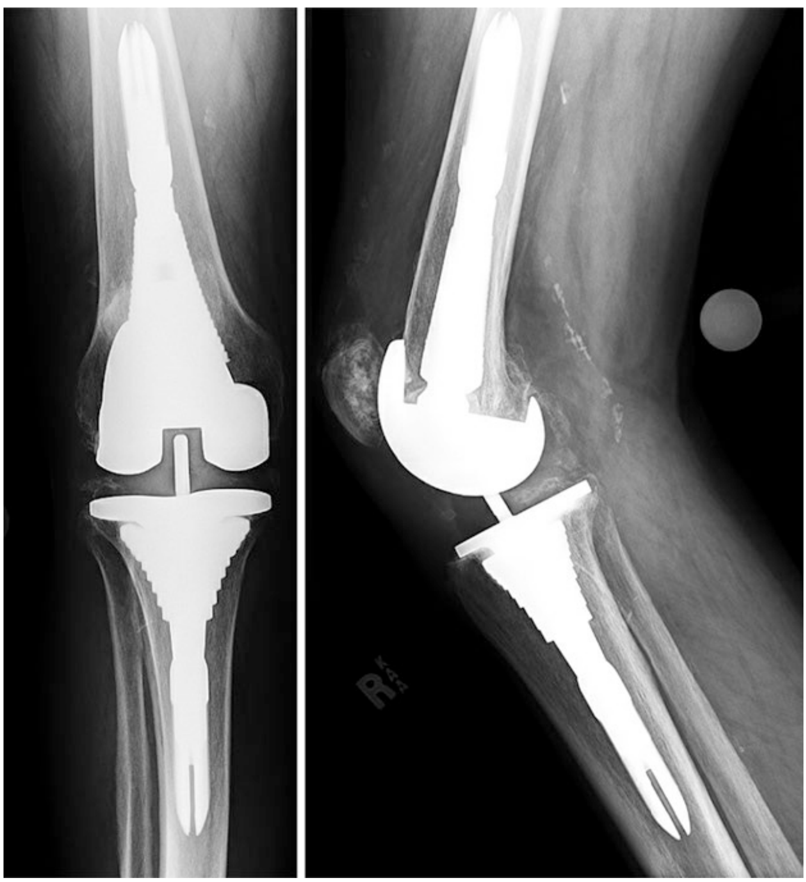

Fig. 42.2 Postoperative standing AP and lateral X-rays showing the use of femoral and tibial sleeves with press-fit fluted stems

42.4 Discussion

Metaphyseal sleeves provide axial and rotational stability while managing a wide array of bone defects encountered during RKA. Furthermore, sleeves address shortcomings (i.e., disease transmission, nonunion, and graft resorption) and provide several advantages when compared to grafting techniques: shorter operative times, reproducible technique, and transferring loads to intact host bone. Potential downsides to sleeve use involve subsequent removal, fracture during implantation, junctional failure, lack of offset adjustability, and implant system cross-compatibility. Current literature demonstrates excellent outcomes in both septic and aseptic revision setting using metaphyseal sleeves.

Bloch et al. retrospectively reviewed 277 patients (48% male; mean age 70 years) who underwent 319 RKA procedures and received metaphyseal sleeves (319 tibial and 146 femoral) with a mean follow-up of 7.5 years, and 73 patients were followed for more than 10 years [10]. Bone loss classification was not provided. At final follow-up, implant survivorship was 99.1%, 98.7%, and 97.8% at 3, 5, and 10 years, respectively. Five patients required re-operation, four due to infection, and one for instability. Three of the infected patients required removal of implants while the fourth was successfully treated with debridement, antibiotics, and implant retentions (DAIR). Radiographic analysis revealed radiolucent lines in nine tibial sleeves (2.8%) and four femoral sleeves (2.7%); none progressed and none were revised. Twelve tibial sleeves (3.7%) had >1 mm subsidence, all stabilized, and none required revision.

Klim et al. retrospectively analyzed 56 patients (61% female, mean age 73 years, and mean BMI 30) with a history of periprosthetic joint infection who underwent two-stage RKA with the use of porous-coated sleeves (65 tibial and 43 femoral) and a mean follow-up time of 5.3 years [11]. Bone loss classification performed preoperatively included AORI type 2a (20 tibial and 13 femoral), type 2b (37 tibial and 26 femoral), and type 3 (8 tibial and 4 femoral). Nine patients had to be re-revised at final follow-up all due to recurrent infection; no cases of aseptic loosening were encountered. Radiographic analysis of patients without re-revision (47 patients) showed osseointegration in all but 2 patients (4.2%; mean follow-up 7.7 years) who had radiographic signs of loosening but minimal clinical signs or symptoms of loosening. The Western Ontario and McMaster Universities (WOMAC) score improved by a mean of 28 points. The mean postoperative Knee Society Score (KSS) was 76; no preoperative values were provided.

A systematic review by Zanitaro et al. reviewed 37 articles including both metaphyseal cones and sleeves following the PRISMA 2009 guidelines [12]. Results of 1801 metaphyseal sleeves with mean follow-up of 4.5 years were included. The aseptic survivorship of the sleeves was 97.8%.

42.5 Summary

Metaphyseal sleeves are now frequently used in the RKA setting to address a wide spectrum of bone defects. At the moment, clinical data are reassuring and support the continued use of sleeves, although more long-term data are needed to evaluate their advantages and limitations. Furthermore, it will help steer the direction for future designs in order to maximize the effectiveness of sleeve-based constructs.

References

1. Sloan M, Premkumar A, Sheth NP. Projected volume of primary total joint arthroplasty in the U.S., 2014 to 2030. J Bone Jt Surg – Am Vol. 2018;100:1455–60.
2. Singh JA, Yu S, Chen L, Cleveland JD. Rates of total joint replacement in the United States: future projections to 2020-2040 using the national inpatient sample. J Rheumatol. 2019;46:1134–40.
3. Bozic KJ, Kurtz SM, Lau E, Ong K, Chiu V, Vail TP, et al. The epidemiology of revision total knee arthroplasty in the United States. Clin Orthop Relat Res. 2010;468:45–51.
4. Sheth NP, Bonadio MB, Demange MK. Bone loss in revision total knee arthroplasty: evaluation and management. J Am Acad Orthop Surg. 2017;25:348–57.

5. Hamilton DF, Howie CR, Burnett R, Simpson AHRW, Patton JT. Dealing with the predicted increase in demand for revision total knee arthroplasty: challenges, risks and opportunities. Bone Jt J. 2015;97-B:723–8.
6. Engh GA, Ammeen DJ. Classification and preoperative radiographic evaluation: knee. Orthop Clin North Am. 1998;29:205–17.
7. Morgan-Jones R, Oussedik SIS, Graichen H, Haddad FS. Zonal fixation in revision total knee arthroplasty. Bone Jt J. 2015;97-B:147–9.
8. Graichen H, Scior W, Strauch M. Direct, cementless, metaphyseal fixation in knee revision arthroplasty with sleeves-short-term results. J Arthroplasty. 2015;30:2256–9. https://doi.org/10.1016/j.arth.2015.06.030.
9. Scior W, Chanda D, Graichen H. Are stems redundant in times of metaphyseal sleeve fixation? J Arthroplasty. 2019;34:2444–8. https://doi.org/10.1016/j.arth.2019.05.031.
10. Bloch BV, Shannak OA, Palan J, Phillips JRA, James PJ. Metaphyseal sleeves in revision total knee arthroplasty provide reliable fixation and excellent medium to long-term implant survivorship. J Arthroplasty. 2020;35:495–9. https://doi.org/10.1016/j.arth.2019.09.027.
11. Klim SM, Amerstorfer F, Bernhardt GA, Sadoghi P, Gruber G, Radl R, et al. Septic revision total knee arthroplasty: treatment of metaphyseal bone defects using metaphyseal sleeves. J Arthroplasty. 2018;33:3734–8. https://doi.org/10.1016/j.arth.2018.08.017.
12. Zanirato A, Formica M, Cavagnaro L, Divano S, Burastero G, Felli L. Metaphyseal cones and sleeves in revision total knee arthroplasty: two sides of the same coin? Complications, clinical and radiological results—a systematic review of the literature. Musculoskelet Surg. 2020;104:25–35. https://doi.org/10.1007/s12306-019-00598-y.