Chapter 12
Revision Total Knee Arthroplasty: Management of Bone Loss

Robert M. Molloy and Nicholas T. Ting

12.1 Case Presentation

A 69-year-old man, otherwise active and healthy, presented to clinic with a 1-year history of a painful right total knee arthroplasty (TKA), worse in the last 6 months. Pain was worse with activity, although he was able to ambulate for ten blocks without the use of any assist devices. He denied any precipitating trauma or injury, as well as any constitutional symptoms or history of painful TKA. Past history revealed staged, bilateral total knee arthroplasties performed approximately 15–20 years prior. He stated that up until 1 year ago, he had had an otherwise unremarkable postoperative course. Physical examination of his right knee revealed no effusion, warmth, or erythema; his previous midline incision was well healed. He demonstrated some pain with active range of motion from 5° to 130°, as well as increased varus/valgus laxity. Routine radiographs revealed bilateral TKAs with signs of significant osteolysis, component loosening, and subsidence (Fig. 12.1). Right knee X-rays demonstrated a cruciate retaining cemented, modular TKA with loosening of the

R.M. Molloy, MD (✉) • N.T. Ting, MD
Department of Orthopedic Surgery, Cleveland Clinic,
9500 Euclid Avenue, Cleveland, OH 44195, USA
e-mail: molloyr@ccf.org

B.D. Springer and B.M. Curtin (eds.), *Complex Primary and Revision Total Knee Arthroplasty: A Clinical Casebook*,
DOI 10.1007/978-3-319-18350-3_12

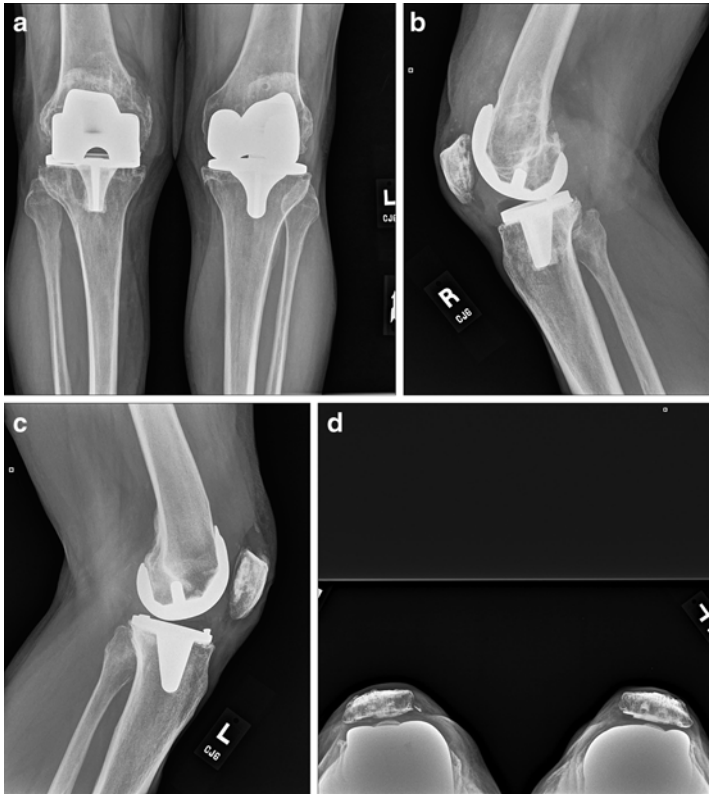

FIG. 12.1. (**a**–**d**) Preoperative X-rays reveal a cemented right and left total knee arthroplasties with radiographic signs of loosening. The right TKA tibial component has subsided into varus.

femoral and tibial components, the latter having subsided into varus; there were significant osteolytic lesions surrounding both components. While there was no distinct metal-line sign present [1], there was radiographic densification of the periarticular soft tissue seen on the lateral view. Of note, left knee X-rays revealed a similar pattern. Serum erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP) were 1 mm/h (normal range, 0–15 mm/h) and 0.1 mg/dL

(normal range, 0.0–1.0 mg/dL), respectively. Serum cobalt and chromium levels were elevated to 12 μg/L (normal range, <1.0) and 3.9 μg/L (normal range, 0.2–0.6).

12.1.1 Diagnosis/Assessment

The patient presented with a chronically painful right TKA and late instability in the setting of elevated serum metal ion levels, and hence was presumed to have full-thickness polyethylene wear and resultant osteolysis. The index of suspicion for this was high on the left knee as well, but our work-up and treatment focused on his symptomatic right TKA. Chronic, indolent periprosthetic infection could not be ruled out either, but his history, physical exam, and laboratory results suggested an aseptic etiology; hence, a preoperative knee aspiration for synovial analysis was deferred in lieu of an intraoperative assessment. Historically, polyethylene wear and its sequelae (aseptic loosening, osteolysis, late instability) are common causes for revision total knee arthroplasty, particularly with the use of modular tibial components. In fact, osteolysis induced by wear debris of ultra-high-molecular-weight polyethylene emerged as a significant problem, presumably related to backside polyethylene wear as well as poor quality polyethylene (i.e., gamma irradiated in air). While a rare cause of failure after total knee arthroplasty, metallosis was also considered in this case given the significant osteolysis, joint space narrowing, and radiographic densification of the periarticular soft tissue seen radiographically [2]. Metallosis has only previously been reported when there has been abnormal metal-on-metal contact, and we suspected this phenomenon here, prompting our preoperative interest in serum metal ion levels.

12.1.2 Management

In a patient with presumed metallosis, osteolysis, and aseptic loosening due to full-thickness polyethylene wear, revision TKA involving all components must be discussed. In particular, the

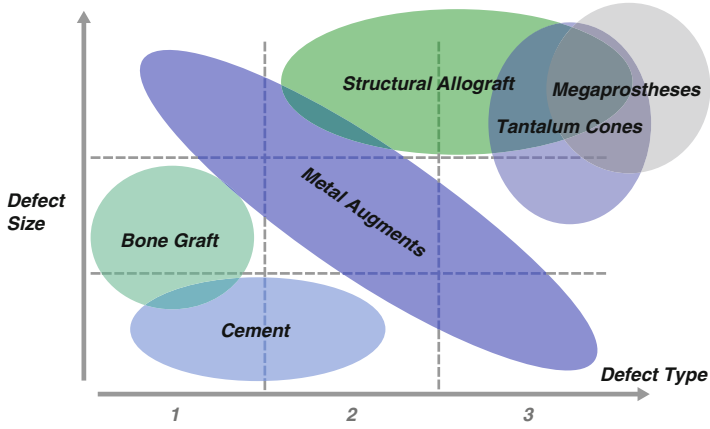

FIG. 12.2. Matrix of bone loss filling options in revision TKA. *X*-axis represents the relative defect size, while the *y*-axis represents the defect type, according to the Anderson Orthopedic Research Institute (AORI) classification.

method of reconstruction depends on the remaining bone stock, ligamentous integrity, and the ability to balance flexion/extension gaps. The Anderson Orthopedic Research Institute (AORI) classification grades bone loss associated with revision TKA based on defect size and the degree of metaphyseal involvement [3]. This provides a useful guide for predicting the options for reconstruction. Cement, morselized allograft, or metal augments can be individually used to fill smaller, confined defects (<1 cm). As the defect size or degree of metaphyseal involvement increases, reconstruction may require impaction grafting, structural allograft, metaphyseal sleeves, porous metal cones, composite allograft, megaprostheses, or some combination of any of these modalities (Fig. 12.2). While preoperative radiographs can predict the anticipated bone loss, they often underestimate the actual bone loss encountered intraoperatively [4]. Hence, adequate preoperative planning means anticipating the use of any combination of the aforementioned defect-filling modalities.

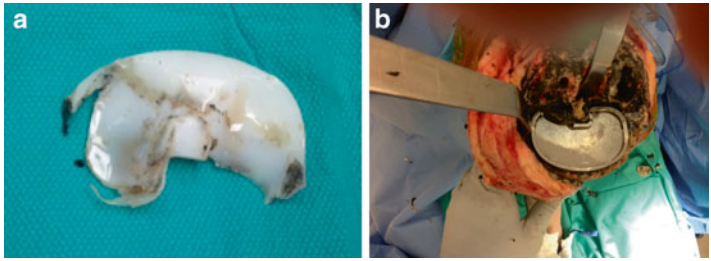

FIG. 12.3. There is full-thickness wear of the polyethylene insert, most prominently on the posterolateral corner (**a**), and a corresponding completely worn corner of the tibial base plate beneath it (**b**).

12.1.3 Outcome

The patient underwent elective revision TKA after thorough discussion about the potential bone loss and the spectrum of possible treatment options; while less likely, the potentials for underlying periprosthetic infection and two-stage revision were also discussed. At the time of surgery, there was extensive metallosis and metallic debris, but intraoperative frozen sections were unremarkable for acute inflammation. On gross examination, the all-polyethylene patellar button was frankly loose, and there was significant femoral component burnishing. There was full-thickness wear of the polyethylene insert, most prominently on the posterolateral corner, and a corresponding completely worn corner of the tibial base plate beneath it (Fig. 12.3). Removal of all hardware revealed significant osteolysis of both the distal femur and proximal tibia with type III bone defects, as classified by the AORI scale. On the femoral side, only a shell of bone remained medially, with a significant osteolytic defect on the lateral side as well (Fig. 12.4a). On the tibial side, there was a significant osteolytic defect centrally (Fig. 12.4b). The femoral defect was filled with a trabecular metal distal femoral cone and a press-fit stem, along with bilateral distal femoral and posterior augments (Fig. 12.5a). Likewise, the tibial defect was addressed with a trabecular metal cone with a press-fit

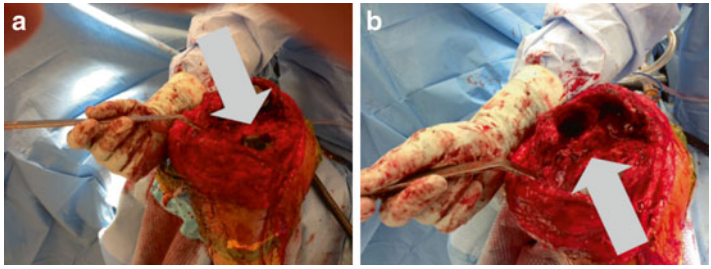

FIG. 12.4. In the femur, there is only a shell of bone remaining on the medial side and a significant osteolytic defect laterally (**a**). There is a significant osteolytic defect centrally seen in the tibia (**b**).

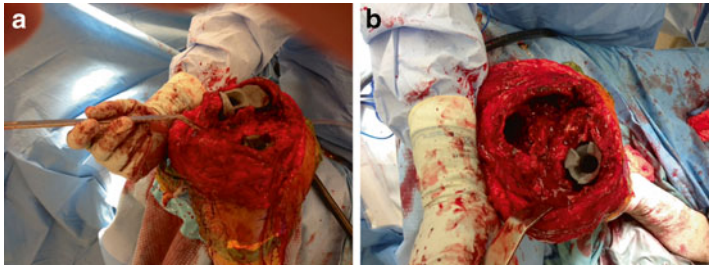

FIG. 12.5. Trabecular metal cones are seen filling defects in the distal femur (**a**) and proximal tibia (**b**).

stem and bilateral tibial augments (Fig. 12.5b). A total stabilized insert was used to address ligamentous instability. Postoperatively, the patient was restricted to 20 lbs-weight bearing for 6 weeks in a hinged knee brace, locked from 0° to 90°. At his 8-week postoperative follow-up visit, he was already weight bearing as tolerated without a brace and demonstrated an active range of motion from 0° to 130°. He did complain of some new-onset, mid-shaft tibial pain, which was mild in nature and unrelated to any injury or other symptoms. His radiographs demonstrated stemmed femoral and tibial components in good overall alignment (Fig. 12.6). There was no evidence of fracture or loosening, and we attributed this pain to modulus mismatch with the press-fit tibial stem.

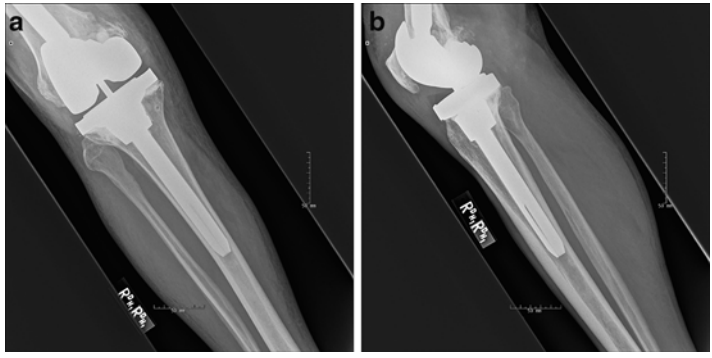

FIG. 12.6. Postoperative week 8 AP (**a**) and lateral (**b**) radiographs demonstrate stemmed femoral and tibial components in good overall alignment.

12.2 Literature Review

Bone loss is a common problem in revision total knee arthroplasty. In this case, the extensive bone loss was a result of osteolysis secondary to polyethylene wear and metallosis; however, the etiology of bone deficiency can also include aseptic loosening resulting in direct mechanical bone loss, septic loosening, instability stress shielding, or iatrogenic during implant removal. No two revisions are the same. As the type of bone loss can be highly variable in each case, so too are the potential reconstruction options.

In the management of bone loss, it is important to consider defect size and location, as well as patient-specific characteristics such as age, life expectancy, body mass index, and activity level. As aforementioned, one widely used method for categorizing defects based on size and metaphyseal involvement is the AORI classification outlined by Engh. Type 1 defects involve an intact metaphyseal rim and joint line with bone defects of less than 1 cm; these defects can be reconstituted with cement, morselized allograft, or metal augments. Type 2 defects involve significant cancellous bone loss with a

Table 12.1. Management of bone loss in revision total knee arthroplasty.

Defect type	Defect size	Treatment options
Contained	<5 mm	PMMA fill
	5–10 mm	Reinforced PMMA
	>10 mm	Morselized allograft or porous metal augments
Non-contained	<5 mm	PMMA
	5–10 mm, <50 % femoral condyle/tibial plateau	Reinforced PMMA
	5–15 mm, >50 % femoral condyle/tibial plateau	TKA modular systems with stems, augments
	>15 mm	Structural allografts; megaprostheses, or porous metal augments

Abbreviations: *PMMA* polymethylmethacrylate (acrylic bone cement), *TKA* total knee arthroplasty

relatively intact metaphyseal rim and require joint line restoration; these defects are further categorized into type 2a (only one femoral condyle or one side of the tibial plateau involved) and type 2b (both femoral condyles or both sides of the tibial plateau involved). Reconstruction options for type 2 defects include metal augments, impaction grafting, structural allograft, metaphyseal sleeves, or porous metal cones. Type 3 defects involve large metaphyseal rim defects with extensive cancellous bone loss; reconstruction options include impaction grafting, structural allograft, metaphyseal sleeves, porous metal cones, composite allograft, or megaprostheses. Another classification scheme, outlined by Clatworthy and Gross (Table 12.1), categorizes defects initially as contained or non-contained. Defects can be further stratified as type I—contained with metaphyseal bone intact, in which restoration of the joint line does not require bone grafting or augmentation; type II—contained with compromised metaphyseal bone and requiring bone grafting, cement fill, or augments to restore the joint line; type III—non-contained, noncircumferential defects requiring a femoral head

allograft, partial distal femur, or partial proximal tibia; and type IV—non-contained, circumferential defects requiring a segmental distal femoral or proximal tibial graft.

The armamentarium of treatment options for bone loss is extensive, including polymethylmethacrylate (PMMA) with or without reinforcing screws, autograft, morselized or structural allograft [5], modular TKA systems including stems, wedges and metal augments, and orthopedic salvage systems such as mega- or tumor prostheses [6]. For reconstitution of contained defects, morselized allograft is better suited than structural allograft and may be associated with a higher rate of incorporation. However, the drawbacks of allograft use include late resorption, fracture or nonunion in the case of structural allograft, and risk of disease transmission. Other alternatives to small, contained defects include filling with PMMA, reinforced with one or more screws if the defect is larger enough. Metallic augments available with modular TKA systems can also be used to address areas of discrete bone loss.

12.2.1 Ultraporous Metals

Ultraporous metals fabricated into augments and cones, such as those used in this patient, are helpful innovations for addressing larger structural defects in revision TKA [7–9]. While there is a paucity of information in the literature regarding the long-term outcomes of these reconstruction options, short-term results have been promising. Meneghini et al. [10] reported on the use of porous tantalum augments for treatment of extensive tibial bone loss in a series of 15 revision TKAs (15 patients) that included seven AORI type 2B and eight type 3 defects. At a mean follow-up of 34 months, all cases went on to osseointegration without loosening or migration. More recently, Huang et al. prospectively followed 83 knees that underwent revision TKA with metaphyseal sleeves [11], including 36 sleeves used in femoral revisions and 83 sleeves in tibial revisions. At a mean follow-up

of 2.4 years, none of the implants demonstrated progressive radiolucency around the metaphyseal sleeves, and only two (2.7 %) patients required revision for aseptic loosening of their tibial components.

12.2.2 Salvage Prostheses

As bone loss becomes more severe, both in size and containment, revision options expand to include tumor-type megaprostheses [6]. Distal femoral replacements have been utilized for a variety of indications, ranging from severely comminuted periprosthetic fractures compromising implant fixation to catastrophic revision scenarios involving severe osteolysis, septic failure, or ligamentous instability. Berend et al. reported on a series of 38 distal femoral replacements in 36 patients with a mean follow-up of 33 months [6]. The most common indications were periprosthetic fracture (32 %), septic failure (21 %), and aseptic loosening (18 %). The average size of bone loss encountered was 7 cm. Complications included two deaths within 3 months of surgery and three reoperations—two for recurrent infection and one for periprosthetic fracture.

In their review of the literature, Lombardi et al. offered an algorithmic approach to managing bone loss in revision TKA [12]. PMMA cement alone can be used for bone defects <5 mm in size. For deficits of 5–10 mm and <50 % of the femoral condyle or tibial plateau, PMMA with reinforcing screws is recommended. Morselized allograft can be used to fill contained deficits >5 mm. For non-contained defects 5–15 mm and >50 % of the femoral condyle and tibial plateau, they recommend modular TKA systems with stems and augments. And in the case of non-contained deficits >15 mm, structural allografts, tumor-type megaprostheses, and porous metal augments provide suitable options.

12.3 Clinical Pearls/Pitfalls

- Bone loss is a common problem in revision total knee arthroplasty.
- Metallosis must be considered in the setting of the chronically painful TKA with radiographic signs of osteolysis and component loosening.
- While preoperative radiographs can predict the anticipated bone loss, they often underestimate the actual bone loss encountered intraoperatively.
- Preoperative and intraoperative classification of bone deficiency can predict the options for reconstruction.
- As there is a spectrum of bone-filling options, reconstitution of bone defects often involves more than one modality of treatment.
- At short-term follow-up, revision TKA with each of the different modes of bone reconstitution provides reliable fixation.

References

1. Weissman BN, Scott RD, Brick GW, Corson JM. Radiographic detection of metal-induced synovitis as a complication of arthroplasty of the knee. J Bone Joint Surg Am. 1991;73:1002–7.
2. Romesburg JW, Wasserman PL, Schoppe CH. Metallosis and metal-induced synovitis following total knee arthroplasty: review of radiographic and CT findings. J Radiol Case Rep. 2010;4: 7–17.
3. Engh GA, Ammeen DJ. Bone loss with revision total knee arthroplasty: defect classification and alternatives for reconstruction. Instr Course Lect. 1999;48:167–75.
4. Mulhall KJ, Ghomrawi HM, Engh GA, Clark CR, Lotke P, Saleh KJ. Radiographic prediction of intraoperative bone loss in knee arthroplasty revision. Clin Orthop Relat Res. 2006;446:51–8.
5. Burnett RS, Keeney JA, Maloney WJ, Clohisy JC. Revision total knee arthroplasty for major osteolysis. Iowa Orthop J. 2009;29: 28–37.
6. Berend KR, Lombardi Jr AV. Distal femoral replacement in nontumor cases with severe bone loss and instability. Clin Orthop Relat Res. 2009;467:485–92.

7. Radnay CS, Scuderi GR. Management of bone loss: augments, cones, offset stems. Clin Orthop Relat Res. 2006;446:83–92.
8. Patil N, Lee K, Goodman SB. Porous tantalum in hip and knee reconstructive surgery. J Biomed Mater Res B Appl Biomater. 2009;89:242–51.
9. Levine B, Sporer S, Della Valle CJ, Jacobs JJ, Paprosky W. Porous tantalum in reconstructive surgery of the knee: a review. J Knee Surg. 2007;20:185–94.
10. Meneghini RM, Lewallen DG, Hanssen AD. Use of porous tantalum metaphyseal cones for severe tibial bone loss during revision total knee replacement. Surgical technique. J Bone Joint Surg Am. 2009;91 Suppl 2 Pt 1:131–8.
11. Huang R, Barrazueta G, Ong A, et al. Revision total knee arthroplasty using metaphyseal sleeves at short-term follow-up. Orthopedics. 2014;37:e804–9.
12. Lombardi AV, Berend KR, Adams JB. Management of bone loss in revision TKA: it's a changing world. Orthopedics. 2010;33:662.