Bone loss and subsequent defects are often encountered in revision total knee arthroplasty and occasionally in primary total knee arthroplasty. The variability in size and location of these defects has led to the development of a multitude of techniques aimed at restoring the physical integrity of the knee and supporting prosthetic replacement. Techniques frequently reviewed in the literature include filling minor defects with cement; augmentation of cement with screws, wires, or mesh; bone grafting; metal augmentation with blocks or wedges; and custom components.

Modularity in total knee systems has earned its acceptance by providing utility in the management of this wide spectrum of bony defects. Consequently, as the array of modular options including offset stems, stem extensions, variable femoral and tibial prosthetic body options, and modular augmentations have evolved, custom implants are now rarely needed. The clinical acceptance of modular metal wedges and blocks is due in large part to their effectiveness in managing the variety of clinical situations that face the knee arthroplasty surgeon.

Bone defects that remain contained by the cortical rim, both in the tibia and in the femur, are generally best managed with bone grafting techniques. A number of authors have reported success using structural as well as morsellized allograft in these contained defects. For very large contained defects, a combination of bulk and morsellized graft may be most appropriate, usually offloaded with extended prosthetic stems.

When the cortical rim of either the distal femur or proximal tibia is breached, the reconstructive options are challenging. In younger patients, structural allograft may be an option for consideration, yet this is tempered by reported problems including host-graft nonunion, disease transmission, and possible late collapse or resorption of the allograft. Indeed, there is a trend in revision centers away from bulk, structural allograft when other options are readily available.

Surgical techniques other than the use of modular or custom implants include shifting of the prosthesis to a region of more supportive host bone stock and/or possibly downsizing the prosthesis. These intraoperative choices represent compromises that may be accompanied by potentially undesirable consequences. On the tibial side, downsizing the tray and shifting away from a compromised cortical rim results in increased unit force transmission across the component to the underlying bone. Reduction of cortical rim contact coupled with an increased reliance on cancellous bone, tray subsidence may result. One clinical study suggests that translation of the tibial tray greater than 4 mm may lead to higher component loosening and failure. Downsizing of a femoral component to accommodate anterior or posterior bone loss may inadvertently lead to flexion space instability.

Recognition of the limitations associated with the techniques mentioned previously led to the development of modular metal wedges and block augmentations. The first wedged augmentation of a tibial component was reported by Jeffery et al. The first clinical series reporting use of modular metal wedges for the management of bone deficiency was by Brand et al. in 1989. Modular metal augmentations are now readily incorporated in modern knee reconstruction systems. In this chapter we discuss the relative indications for femoral or tibial augmentations with modular augments, the justification for their use in modern reconstructive surgery, limitations with this approach, and techniques employed.
BONE LOSS: GENERAL CONSIDERATIONS

Bone deficiencies and bone loss are encountered in both primary and revision settings. In a primary knee extreme varus, valgus, or flexion deformities may preoperatively herald the presence of bone defects, which, if ignored, may threaten the component reconstruction. Varus or valgus angulation, in the extreme, can lead to significant bone loss on either the tibial or femoral side of the joint. Although such extreme defects are less commonly encountered in primary knee arthroplasty in clinics today, progressive or rapid bone loss associated with avascular necrosis, neglect, or trauma may result in bone defects that require augmentation. Inflammatory arthropathy, such as rheumatoid arthritis, may result in severe cyst formation and bone loss.

The bone defects seen in revision knee arthroplasty generally occur with component loosening, component removal, or from osteolysis. Several authors have described classification schemes for bone loss about the knee. Deficiencies on the tibial side are typically central cavitary, peripheral, or a combination. On the femoral side, the loss of structural host bone that requires augmentation is usually distal or posterior (Figure 9-1). Obviously, multiple permutations of any bone loss classification schemes are seen clinically, depending in large part on the mode of failure, the failed component type, and preexisting host bone stock. The most common patterns of bone loss that require modular augmentation include medial tibia in association with varus angulation, lateral tibial augmentation seen with valgus failure, and a combination of distal and posterior femoral augmentation with component failure.

Preoperative radiographs can help identify patients who may require tibial or femoral augmentation. Brand et al. have proposed a method for estimating tibial defect size based on the anaesthesia of the preoperative anterior-posterior radiographs. This technique is illustrated in Figure 9-2. A line is drawn down the central axis of the tibia. A perpendicular line is then drawn at the top of the intact tibial plateau. A second perpendicular line is extended to the base of the tibial defect. A differential measurement, corrected for magnification, exceeding 15 mm may require augmentation and should be considered in preoperative planning of the reconstruction.

Estimation of the need for augmentation on the femoral side is slightly more difficult. The 3-dimensional shape of the distal femur captured on 2-dimensional film, along with the metallic bulk of the femoral implant, make visualization of the distal femur difficult. Additionally, the bicondylar overlay on lateral films may lead to underestimation of unicompartmental defects. Although oblique x-rays may be of benefit, evolving computed tomography techniques with subtraction algorithms hold great promise for accurate preoperative prediction of bone loss. Addi-

FIGURE 9-1. Modern revision knee systems allow for the use of augments of varying thickness, as here on the posterior and distal femur.

FIGURE 9-2. The size of a peripheral tibial defect can be measured off the reconstructed joint line based on the uninvolved side. (Adapted from Mason and Scott by permission of Lippincott Williams & Wilkins.)