Revision total knee arthroplasty can be one of the most gratifying procedures performed by a joint replacement surgeon. The painful, unstable failed knee replacement can be made stable and pain-free with careful, well-planned surgery. To be successful, revision knee arthroplasty requires careful preoperative assessment, precise planning, and excellent surgical technique. These principles have been reviewed in great detail in earlier chapters. They should be applied in every revision case no matter the perceived complexity. In complex cases, however, strict adherence to these principles is absolutely necessary for a successful outcome. The goals of revision total knee arthroplasty are the same as in primary total knee replacement: a stable, pain-free knee with functional range of motion to allow locomotion. Several factors contribute to achieving these goals. The patient must have sufficient motor power to support body weight. Knee stability must be achieved through proper soft tissue tensioning or ligament substitution. Knee motion must be sufficient to support the desired function. Finally, implants must achieve stable and durable fixation on the host skeleton. All subsequent function relies on this final tenet. A custom-designed implant makes this possible in the most difficult of cases. In this chapter, we outline the preoperative assessment and surgical planning as they relate to deciding on a custom implant. We review specific cases in which such an implant may be useful.

Custom knee revision implants are used when there are bone deficiencies or anatomic distortions severe enough that modular revision knee systems and simple allografts are insufficient to allow predictable implant stability on viable host bone strong enough to withstand the anticipated loads. Modular augments are too small, offset options for stems are limited, and augmentation with structural allograft is unpredictable and time-consuming to fashion. Extreme failures call for innovative solutions. Custom-designed implants can be used to more predictably solve complex cases with massive bone loss. Critical to the successful use of custom implants is identifying those situations in which their use is necessary, assisting the engineer to correctly size and design the implant, having the instruments necessary for implantation, and creating a backup plan in the unlikely event that the surgical plan must be altered.

A custom implant is designed to fit one particular patient’s anatomy. It is designed and manufactured by engineers based on preoperative radiographs, with the design directed by the operative surgeon. In custom total knee arthroplasty, the primary goal is to achieve implant stability on viable host bone. Bone deficiencies are replaced, filled, or bypassed by the metal of the custom implant. The chief alternative to this method of reconstruction, the use of bulk structural allograft, offers several advantages, including its relative economy compared with customs, the ability for the graft to be modified intraoperatively, and the overvalued potential for restoration of bone stock. The disadvantages are formidable and often underappreciated. The graft may fail to heal to the host bone, leading to failure of the implant. Incorporation of large bulk allografts is unpredictable, with failure of the graft due to resorption and fracture proportionate to the length of time implanted. This failure of the graft is a cause for revision, and we find that the graft that remains is often unsuitable to support a new implant. Clatworthy et al. reported on 52 knees with major osseous defects reconstructed with 66 structural allografts at mean follow-up of 97 months.1 Survivorship of the allograft was 72% at 10 years. Five knees were revised for resorption of the graft and 3 additional knees not revised had evidence of graft resorption despite union at the junction.
The operative complexity of the use of allograft should not be understated. Preoperative sizing of the graft is critical. Grafts that are too large or too small significantly complicate reconstruction. There is commonly a mismatch in the canal size; the graft canal too small due to the young age of the donor with the host canal too large due to age and disuse. Shaping allografts and then fixing them to host bone requires significant time under anesthesia and tourniquet. Finally, the potential for disease transmission, while small, is real and not shared with customs.

Rather than accepting the disadvantages of structural allograft, we prefer to replace or bypass major bone deficiencies with custom implants. Depending on the type and severity of bone loss, some or all of the implant may need to be customized. Sometimes this requires the design of a large segmental replacement on either side of the joint. In many cases, however, modular knee systems can be combined with custom modules—a “focused customization,” as described by S. David Stulberg (personal communication). In areas in which the standard modules of the revision system are inadequate, a custom module is fabricated. The standard instrumentation can be used, and in many cases trial implants can provide a good idea of implant fit and stability. This provides a wider comfort zone for the surgical team. Using a modular revision system as a foundation, stems can be created that have custom offsets, diameters, lengths, coatings, and locking holes. Likewise, wedges with anatomically matched dimensions can successfully bridge defects.

The decision to pursue a custom design is obviously made preoperatively. In templating, the surgeon must be confident that an implant will achieve initial stability on host bone for any chance of durable fixation. Once fixed to host skeleton, metal can be relied on to take loads for decades. Given the importance of preoperative decision making, the quality of preoperative radiographs cannot be overemphasized. Poor radiographs often underestimate bone loss, creating unanticipated problems at the time of reconstruction. A complete set should include long-leg views of both extremities, standing anteroposterior (AP) views of both knees, scaled AP and lateral views of both knees, and sunrise views. Comparing the failed knee with the opposite side allows assessment of bone loss, alignment, and size. The long-leg views provide information about alignment, bone loss, malalignment above and below the joint, internal fixation, or prostheses above and/or below the failed knee. Occasionally, computed tomography (CT) can assist in assessing volume loss from lysis, estimating canal diameters, or more precisely gauging distorted anatomy. The long-leg view helps establish the location of the joint line, the first step toward understanding the needed augmentation. Assessing the amount of bone loss may be difficult where the implant obscures the bone. Areas of osteolysis are frequently subtle and may be underestimated. On the ipsilateral knee film, landmarks such as the femoral epicondyles, the fibular head, and the tibial tubercle can be used as references. A tracing of the more normal side can be used as an overlay on the failed side to help with joint line assessment, component sizing, and bone loss severity.

The major step in surgical planning is the matching of bone loss with reconstruction method. We have simplified the classification of lost bone in total knee replacement into 3 categories: bone defects amenable to reconstruction with the use of augment blocks and wedges (shims); defects significant enough to require metaphysis-fitting cones (sleeves); and extensive defects, usually involving loss of ligamentous attachments, requiring the use of structural metal analogs of the distal femur or proximal tibia (segments). The amount and location of bone loss determines which method—shim, sleeve, segment, or combination of these—will be necessary to achieve implant stability. While shims are commonly available with standard revision knee systems, standardized sleeves and segments are rare. The increasingly severe bone loss found in revision total knee arthroplasty, however, will determine the future off-the-shelf availability of these devices. Sleeves are currently found only with the S-ROM total knee system (DePuy Orthopaedics, Warsaw, IN), although the availability of sleeves and cones will likely be expanded to other systems. Segmental replacements are most commonly found as a portion of tumor devices.

On the femoral side, bone loss that extends only to the epicondyles can usually be managed successfully with modular, off-the-shelf shims, sized to restore the joint line while stem fixation into the diaphysis provides the necessary support for load-sharing. If the bone loss extends into the metaphyseal bone, then prostheses with sleeves may allow sufficient stability on host bone while restoring the joint line. Cone-shaped metallic augments such as sleeves fill the bony defect with metal, which although not restorative of bone stock, does allow the surgeon to bypass poor bone stock in favor of fixation in the metaphyseal flare, where the implant can be wedged for stability. Bone loss that exceeds the metaphysis and extends into diaphyseal bone requires segmental replacement that can only be achieved with either allograft composite implants or custom-designed components.

The revision surgeon should quantify tibial bone loss as well. Cavitary and segmental defects that leave a medial