Patient-Specific Instrumentation for Total Knee Arthroplasty: A Review

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KEYWORDS

• Total knee replacement • Patient-specific instrumentation • Joint arthroplasty
• Computer navigation • Improved accuracy • Surgical efficiency

KEY POINTS

- Patient-specific instrumentation for total knee arthroplasty improves accuracy in coronal alignment compared with standard instrumentation.
- Patient-specific instrumentation for total knee arthroplasty improves efficiency for both low-volume and high-volume joint replacement surgeons.
- Questions remain regarding the cost-effectiveness of patient-specific instrumentation; however, the ability of the technology to alter the fixed cost structure of the operating room through decreased staff and increased surgical volume may show cost-effectiveness over time.

INTRODUCTION

In orthopedics, as in other aspects of medicine, new technology is often introduced with the goal of improving the lives of patients as well as the lives of their physicians. The most successful of these innovations improve simplicity and render treatment more effective, accurate, and efficient. A new technology that promises to achieve these results is patient-specific instrumentation for total knee arthroplasty.

Patient-specific instrumentation involves the use of preoperative advanced imaging techniques, including computed tomography (CT) scan, magnetic resonance imaging (MRI) and full-length radiograph, and rapid prototyping technology to create patient-matched cutting guides that are reverse engineered to reverse glove fit onto the femur and tibia, for use during the bony resections of a total knee replacement. Specific systems allow the surgeon to either cut directly through the custom block or to use a standard cutting block based on the pin placement from the patient-specific guides. This technology determines bony resections, implant rotation, implant position, and implant sizes before surgery with the use of an interactive, computer-based planning tool. During surgery, the surgeon and team are prepared with the proper sizes and do not need to use the standard intramedullary or extramedullary guides. This preparation can reduce the surgical procedure by as many as 21 steps and can reduce the amount of equipment necessary to perform the operation, which not only increases intraoperative efficiency but improves turnover and setup time as well,

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because fewer trays must be processed or opened before surgery.

This technology was introduced to address several challenges currently facing surgeons who perform total knee replacements. Accuracy of component placement has long been considered as paramount to the success of total knee replacements. Several technological advances have been introduced over time, beginning with the first introduction of cutting blocks, in an attempt to make total knee replacement a more accurate and reproducible procedure. However, the limited accuracy of both intramedullary and extramedullary alignment guides have provided an impetus for newer technology to improve the way most knee replacements are performed. Furthermore, the difficulties associated with the implementation of computer-assisted surgery have renewed focus on the ultimate goal of creating an easily implementable technology to improve accuracy and outcomes of total knee replacement. In addition, the current focus on efficiency in the health care system has forced orthopedic surgeons to reexamine their current methods and look for new ways to improve their efficiency without sacrificing patient care.

These challenges have led both surgeons and manufacturers to seek improved efficiency through the use of patient-specific instrumentation for total knee replacement. This technology may offer solutions including improved surgical accuracy and reproducibility, increased operating room efficiency, and, perhaps, decreased overall costs. Other proposed benefits include a possible decrease in intraoperative blood loss, decreased pain, and elimination of fat emboli because there is no need to violate the femoral canal. Also, fewer required instruments could lead to a reduced potential for intraoperative contamination.

SURGICAL TECHNIQUE

When using patient-specific guides for total knee arthroplasty, the procedure begins with the preoperative imaging. Depending on the system being used, the patient undergoes any combination of a CT scan of the knee with limited cuts of the hip and ankle, an MRI of the knee with or without limited cuts of the hip and ankle, and a full-length standing anteroposterior (AP) radiograph. This imaging is then used to create a three-dimensional model of the patient's knee and predetermined anatomic landmarks are identified. Manufacturer-specific algorithms are then applied to the model and femoral and tibial component positioning is determined. The surgeon reviews the proposed plan and any appropriate modifications are made. The disposable, patient-specific guides are then produced using rapid prototyping technology and are delivered for the surgical procedure. In some instances they arrive sterilely wrapped to be opened at the time of the surgery, and, in others, they are sterilized by the hospital before the surgical procedure.

After the surgeon's choice of surgical exposure, the soft tissue is cleared from the femur. Osteophytes should not be removed because they help determine the appropriate orientation of the custom cutting guides. The fabricated guide is placed on the distal femur and secured with pins (**Figs. 1** and **2**). Once the custom femoral guide is in place, it is used to determine the valgus angle, level of resection, AP position, rotation, and size of the femoral component, which allows the elimination of up to 12 steps from the femoral preparation. The remainder of the femoral resections are performed using the standard cutting guide for the anterior, posterior, and chamfer cuts, based on the preoperatively determined size. Once the femur is completed, the tibia is exposed and the custom tibial guide is positioned (**Fig. 3**), again taking care to remove all soft tissue but not disrupt osteophytes, because they are necessary for positioning. With the tibial guide, the surgeon is able to determine tibial alignment, level of resection, slope, and rotation, again eliminating several steps from the procedure. Appropriate soft tissue balancing can then be accomplished with the bony cuts completed. These blocks are only an adjunct to standard technique for component placement, and do not replace careful and appropriate soft tissue balancing.

IMPROVED ACCURACY

As early as 1977, Lotke and colleagues[1] recognized the importance of implant positioning in the

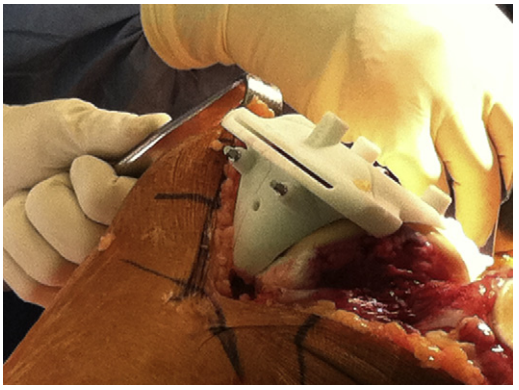

Fig. 1. Lateral view of the patient-specific cutting block for performing the distal femoral resection.

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