Brief Report: Total Knee Arthroplasty Performed with Patient-Specific, Pre-operative CT-Guided Navigation

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ABSTRACT

The clinical success and long-term outcomes of total knee arthroplasty (TKA) are dependent not only on the biomaterials within the prosthetic implant, but also on the surgeon's ability to correctly position the implants onto the bone. Intra-operative computer navigation and robotic surgery have emerged as options to increase the accuracy of implant placement and enhance the outcomes of TKA, with mixed clinical results to date. Pre-operative CT-guided, patient-specific navigation is a unique method for planning TKA surgery to achieving consistent implant positioning, especially for patients with retained surgical hardware or unusual bony anatomy. This technology has been used in Rhode Island in a limited series of patients to assess the utility of the technique and represents an interesting advance for both orthopaedic surgeons and their patients.

KEYWORDS: patient-specific instrumentation, total knee arthroplasty (TKA), CT-guided navigation.

INTRODUCTION

Total Knee Arthroplasty (TKA) is a procedure in which the damaged cartilage surfaces of the knee joint are removed and replaced with smooth articular bearing surfaces. There are many manufacturers who produce TKA implants, and numerous options regarding the design and materials of the prosthetic implants. What is critical across all TKA systems is for the surgeon to place the implants onto the patient's bone in an anatomic fashion. This results in restoration of knee joint biomechanics and optimal longevity of the implants in vivo over many decades of use.

As the manufacturing process for TKA implants has improved over the years, so too has the technology available to surgeons to help place the devices in the most accurate way possible. Advances in surgical cutting jigs, implant designs, sizing options, and bearing surface materials have all been utilized to enhance the outcomes of TKA. More recently, computer navigation and robotic surgery have emerged as intra-operative options to increase the accuracy of implant placement.

Despite the advanced capabilities of these two techniques, their utility is limited by the potentially significant capital investment costs for the relevant technology. Additionally, while some studies have shown improvements in radiographic assessment of implant alignment with computer navigation, no improvements were seen in the long-term implant survival at an average of 10.8 years following computer-navigated TKA compared to conventional TKA.[1] (Studies to date have shown improvements in radiographic implant alignment, but no improvements in short-term knee function or long-term implant survival using computer navigation.)

Preoperative MRI or CT images have been utilized to help plan TKA surgery and generate "patient-specific" custom cutting guides to enhance the accuracy of the procedure. Studies have shown that CT-based navigation can predictably increase the precision of implant placement to within 1.7 degrees of the ideal rotational position[2] but has higher costs compared to "conventional" TKA using standard

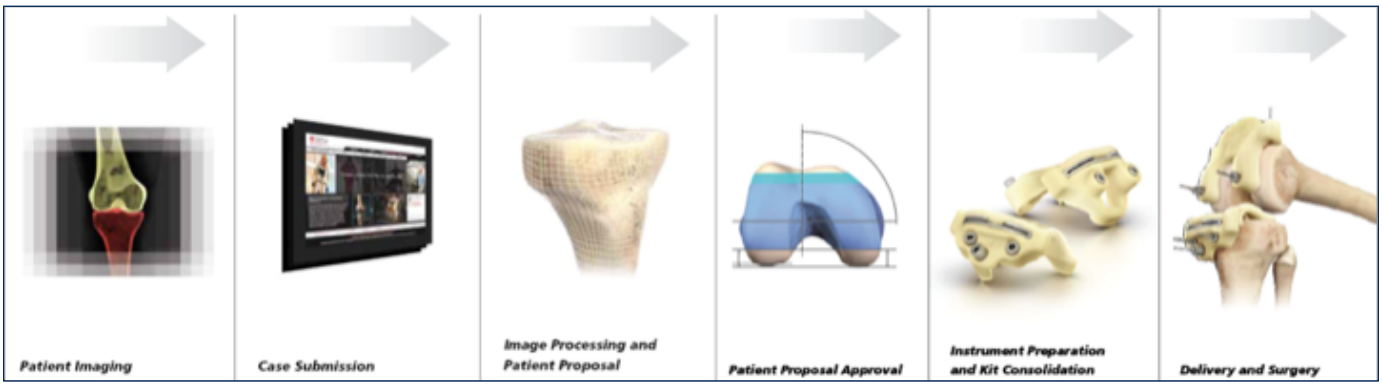
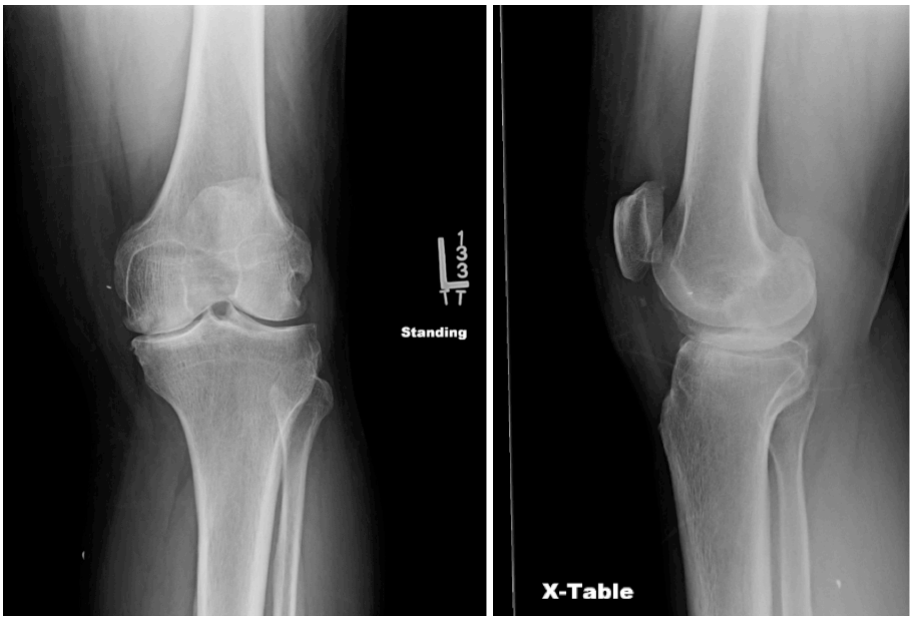


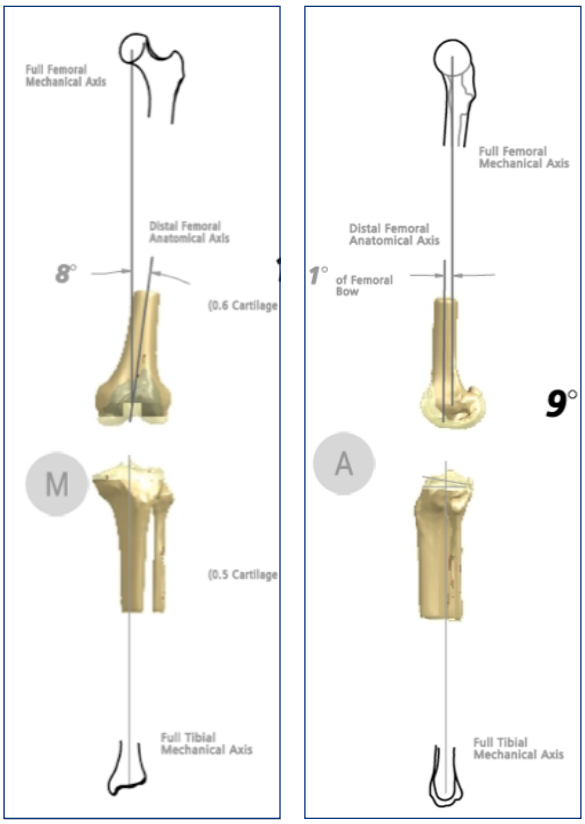
Figure 1. Stepwise method for generating patient-specific cutting blocks using the DePuy TruMatch System.

equipment.[3] Another study showed a 12-minute savings per case in operative time when using the CT-based cutting guides (125.1 minutes versus 137.2 minutes) but also cited cost as potential limitation.[4]

To assist the arthroplasty surgeon with implant choice, sizing selection, and the accuracy of implant placement, a novel technology has been developed for patient-specific instrumentation using pre-operative CT-guided navigation. With this system (TruMatch, DePuy Orthopaedics, Warsaw, IN), a stepwise process is utilized in advance of the TKA surgery (Figure 1). Of note: while a number of other major orthopaedic implant manufacturers (including Smith and Nephew, Biomet, and Stryker) offer the option for pre-operative MRI of the knee joint to create patient-specific cutting guides for TKA surgery, the TruMatch system from DePuy Orthopaedics is currently the only one that utilizes a CT scan from the hip to the ankle to assess and re-create the limb's mechanical axis in a 3-dimensional plane.



Figures 2A and 2B. Preoperative AP and Lateral radiograph of a patient with knee osteoarthritis.

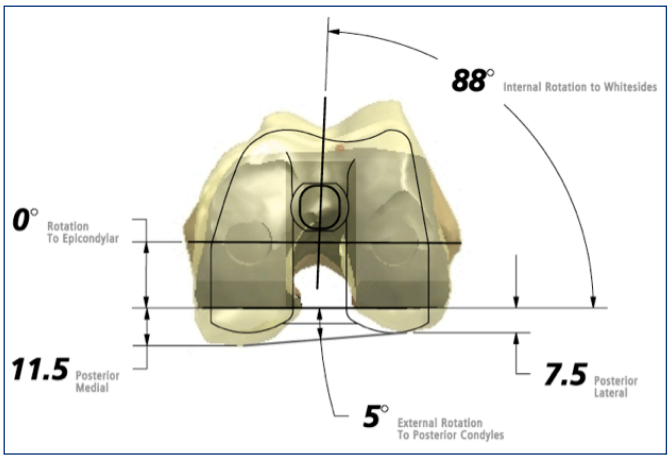


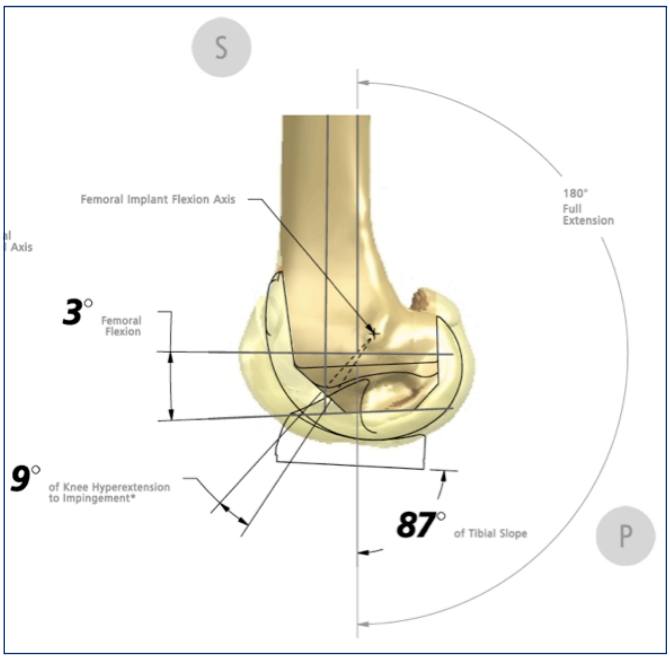
Figures 3A and 3B. CT-scan models determining the AP and Lateral mechanical weight-bearing axis of the operative limb.

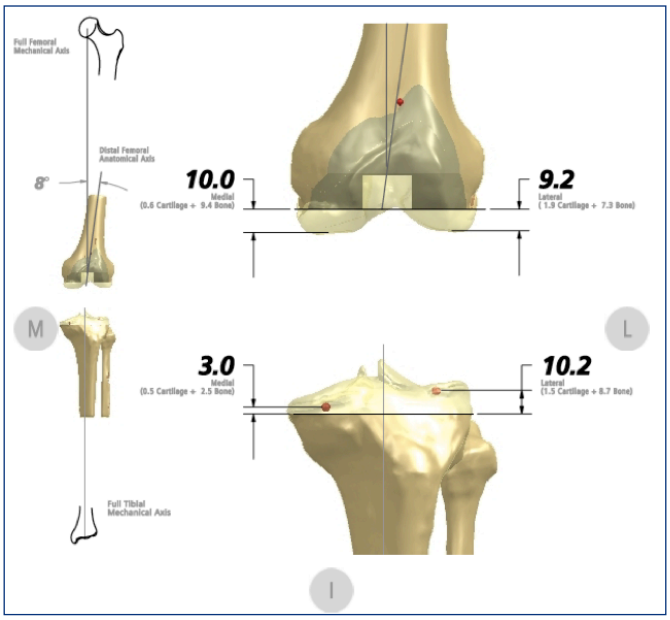
First, a patient is initially assessed with standing knee radiographs to evaluate the severity and location of the osteoarthritis (Figure 2 A and 2 B). Next, a CT scan is obtained from the hip to the ankle, including fine-cut images at the knee joint. A 3-dimensional model of the patient's arthritic knee joint is constructed and reviewed by the surgeon in conjunction with the TruMatch engineering team. This generates a highly detailed rendering of the patient's native bony anatomy and precisely establishes the mechanical weight-bearing axis from the center of the hip to the center of the ankle (Figure 3A and 3B). The program generates a virtual model of how the knee replacement implants will fit the native bone and calculates angular measurements that enable the surgeon to precisely reconstruct the knee before the surgery takes place (Figure 4 A-C). The surgeon interacts with the engineers via a secure web portal; the CT scan images are reconstructed and interpreted by the engineering team remotely in order to create the cutting guides.

The surgeon reviews these images and selects the type of TKA that is optimal, then approves a surgical plan for the patient's operation. The engineers then generate a custom cutting block for both the femur and tibia, which are packaged and sterilized specifically for that individual patient's operation. The cutting guides set the saw blade position during the surgery to allow the surgeon to make bone cuts that align exactly with the pre-operative CT template. Once the bony cuts are complete, the implant is cemented into place, yielding a highly accurate implant position that matches the exact specifications of the preoperative CT scan template (Figure 5A and 5B).

This technology is highly promising as it allows the surgeon to comprehensively understand the 3-dimensional anatomy of a patient's operative knee. By constructing an







Figures 4 A-C. (left) Precise calculation of joint angles, implant position, and bone resections to be used during the surgical procedure.

Figures 5A and 5B. (below) Postoperative AP and lateral views of the left knee following TruMatch TKA showing precise anatomic implant placement.

accurate surgical plan pre-operatively in a virtual environment, changes can be made and problems corrected before reaching the operating room. The TruMatch technology allows for a streamlined operative technique using fewer instruments, and allows for a potentially faster surgical time and operating room turnover.

Importantly, the TruMatch system allows for TKA to be performed in patients with retained surgical hardware in their femur or tibia and for patients with unusual bony deformity, two clinical scenarios that make TKA difficult or impossible using conventional operative techniques.

Patient-specific instrumentation for TKA surgery is an exciting area of advanced technology that will certainly continue to have an impact in the years ahead. Studies will be needed to evaluate the use of this type of technology for conventional knee arthritis surgery, and to compare the outcomes of CT-based versus MRI-based systems for planning customized TKA surgeries in more complex cases.

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Disclosures:

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