Mind the Gap – Achieving a Naturally Balanced and Aligned Knee Following UKA with the MAKOplasty® Procedure

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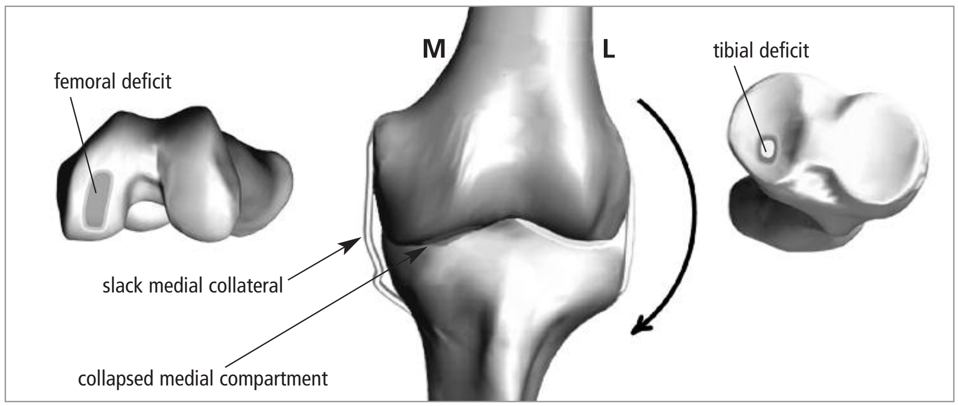
There are distinct differences in the philosophies of post-operative limb alignment between total knee arthroplasty and medial unicompartmental arthroplasty. The goal of TKA is typically to align the post-operative knee in neutral, thus loading both compartments evenly or in slight valgus.[1-3] It has been generally accepted that this is the most important variable predicting survival of the implant.[4] This long-standing goal of TKA has actually been questioned recently, perhaps because the normal knee loads the medial side more than the lateral side.[5]

Figure 1: Medial compartment osteoarthritis results in narrowing of the medial joint space due to the loss of articular cartilage.



With medial UKA, the desired post-operative limb alignment is still unclear. Overcorrection has been implicated as a cause of progression of the disease to the opposite compartment,[6,7] however undercorrection has also been identified as leading to accelerated wear of the polyethylene.[8] With the minimally invasive nature of both the MAKOplasty® procedure and the all polyethylene tibial inlay component, the alignment goal of each component is to match the natural anatomy, thus simply replacing the worn joint surface and restoring the mechanical axis to its position before the onset of degenerative changes.[9-13] MAKOplasty® provides a method for determining where this relative position was before the onset of osteoarthritis. Then, three-dimensional planning of the implant position to achieve this alignment and precise preparation of the bones enables achievement of this alignment post-operatively.

A preliminary plan for the position and orientation of the components is created from a three-dimensional reconstruction of a pre-operative CT scan of the patient's leg and CAD models of the implanted components. This preliminary plan is based primarily on the geometry of the individual bones. During the surgical procedure, standard navigation markers are placed in the femur and the tibia and are also mounted on a robotic arm. A registration procedure consisting of kinematically determining the center of rotation of the hip and digitization of various bony landmarks allows the correlation of the previously reconstructed models of the bones along with their corresponding component plans to the current three-dimensional space of the operating room. Motions of the bones and the robot are continuously monitored in real time.

Once the registration has been completed, osteophytes interfering with medial collateral ligament function are removed and capsular adhesions interfering with knee function are relieved (Figure 1). As two of the indications for a UKA are a correctable deformity and functioning ACL, removal of these impediments makes it possible to achieve correct leg kinematics and tissue tension during passive manipulation throughout the full range of motion with an applied valgus

Figure 2: Manual application of a valgus stress to the knee opens the medial compartment and allows the planning of the placement of the components to fill the articular gap left by the loss of articular cartilage.

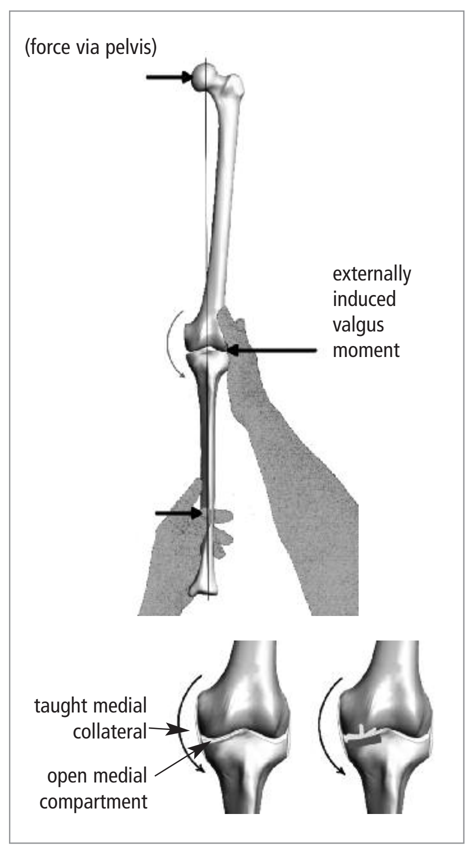
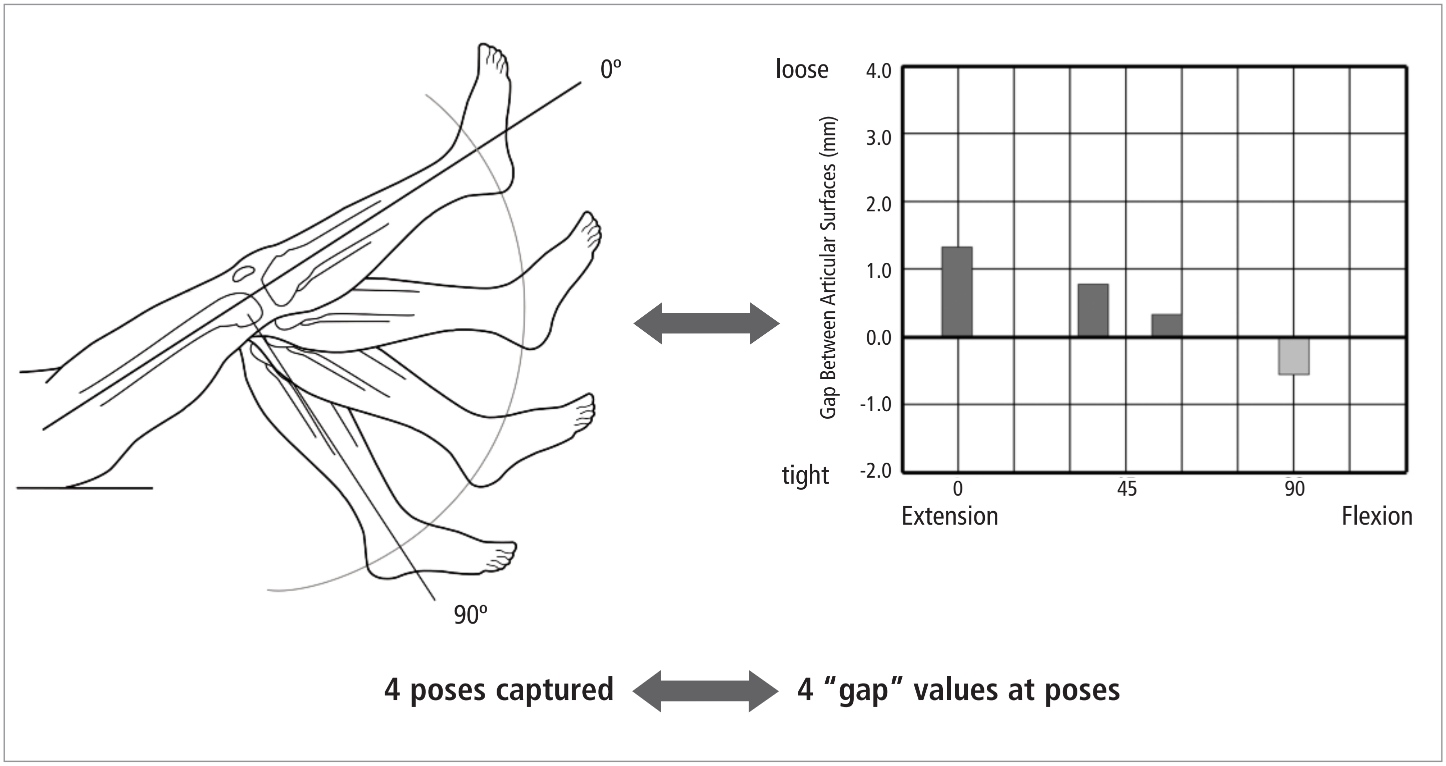


Figure 3: Graph used in planning implant placement at different flexion angles during which the desired limb alignment was captured. The graph displays gap/overlap of the femoral and tibial components. Each component can then be fine-tuned in all 6 degrees of freedom, upon which the graph is immediately updated. This allows the three-dimensional adjustment of implant placement to optimize the desired joint laxity throughout flexion.



stress (Figure 2). Correct leg kinematics and soft tissue tension should represent the relative positioning of the femur and the tibia before the loss of cartilage. The camera system captures the positions of the femur and the tibia during manipulation of the knee through a range of motion with the disease induced varus deformity corrected with an externally applied valgus stress. It should be noted that applying a pure valgus stress becomes more difficult with increasing knee flexion as there is tendency for rotation at the hip. These captured three-dimensional positions represent the appropriate spacing within the joint with the medial collateral ligament properly tensioned. While variability will exist in the manual application of the valgus moment, the high stiffness of the MCL attenuates the manifestation of this variability in the medial joint space opening provided the force is large enough to create a taught collateral. The planned positions of the femoral and tibial components can then be fine-tuned such that the joint articular surfaces are placed to fill the gap left by the disease process throughout the flexion arc (Figure 3). The philosophy being that after resection and component implantation, knee mechanics will be properly restored throughout the range of motion.

This final planned position then defines the volume of bone to be resected by the high speed burr attached to the robotic arm. While inside the volume of bone to be resected, the robotic arm offers no resistance. As the burr approaches the boundary, the robotic arm resists that motion and keeps the burr only within the accepted volume.

The effectiveness of this process is difficult to quantify. A surrogate variable indicative of success is the number of soft tissue releases performed and the number of times the planned insert thickness is not changed intra-operatively. Eighty-nine percent of MAKOplasty® procedures result in the use of the planned insert thickness*,

*Data on file.

6mm, which is the thinnest possible insert. This three-dimensional planning method, which is a combination of pre- and intra-operative planning, empowers the robotic arm to effectively act as a virtual instrument set that precisely assists the surgeon to execute the plan to create an appropriately, naturally balanced and aligned knee.

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