Factors Influencing the Success of Patient Matched Cutting Blocks

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Introduction: The longevity of contemporary total knee replacement strongly relies on joint alignment and soft tissue balance. Constructing cutting blocks based on the patient's anatomy offers unique opportunities to provide customized femoral and tibial resection guides for achieving desired TKA alignment without the use of intra- or extra-medullary rods, potentially also reducing the operating time. This report presents results on femoral and tibial cutting blocks constructed with three different MRI protocols. The blocks were evaluated for ease of placement and stability.

Materials and Methods: Three different MRI protocols (named A, B, and C) were executed on three cadaveric specimens. Protocol A used the spoiled gradient echo technique with a low repetition time (TR) and low echo time (TE) and a flip angle of 30 degrees combined with a fat saturation technique. Protocols B and C used a high TR and a low TE combined with a fat saturation technique. The only difference between B and C protocols is that the protocol B has lower TE than protocol C, which in turn offers more T1 and less PD properties which in turn helps to increase the image contrast within the different tissues in the MR image. Bone models of femur and tibia were extracted from the MR images and appropriate anatomic reference landmarks were identified. Full leg x-rays were used to determine the mechanical axis alignment. Femoral and tibial cutting blocks were then designed through computer aided design (CAD) modeling such that they conform to the bone models on one side for proper seating and have cutting slots at the appropriate resection depth and angle specific to the patient (Figure 1). The cutting blocks were made from medical grade Nylon 12 using EOSint P system (EOS, Krailling Germany). Since the critical surface geometries of these blocks are based on the patient's MRI data set, extreme care must be exercised to ensure the fit and functionality of the blocks. The three fresh frozen human specimens were then prepared exposing the knee joint using a contemporary MIS midline incision and parapatellar, mid-vastus arthrotomy. Each femoral and tibial cutting block was placed on the distal end of the femur and the proximal end of the tibia, respectively. Scale of 1 to 5 was used (5 being the best, 1 being the worst, and 3 or higher as acceptable scores). The blocks were evaluated for ease of placement and stability. In addition, the femoral blocks were evaluated for fit in the region of anterior/lateral trochlear groove, anterior/medial trochlear groove, posterior/medial paddle and the posterior/lateral paddle. The tibial blocks were evaluated for fit in the region of anterior surface, medial paddle, and lateral paddle.

Results and Discussion: The results of the femoral and tibial fits are presented in the Tables 1 and 2. Based on the block evaluations, MRI protocol C was found to produce blocks with better fit. In general, the femoral blocks showed better fit relative to the tibial blocks and this was primarily due to the difference between femoral and tibial bone anatomy. The condylar geometry of the distal femoral bone provides a good surface for the block to sit on. In general, there are several factors other than the MRI protocol which affect the results, including knee joint movement during MR imaging, edge clarity, cartilage visibility, and presence of osteophytes. Previously, Hafez et al. have reported results for similar cutting blocks made from the CT image [1]. However, the study used plastic bone models for comparative trial, which did not have a soft tissue envelope and did not require segmentation. In addition, while CT images show better contrast between bone and soft-tissue, they do not adequately differentiate between articular cartilage and surrounding soft-tissue. As the fit of these blocks depends primarily on the accuracy of the patient's joint anatomy (bone plus articular cartilage), MR imaging is a preferred option over CT imaging.

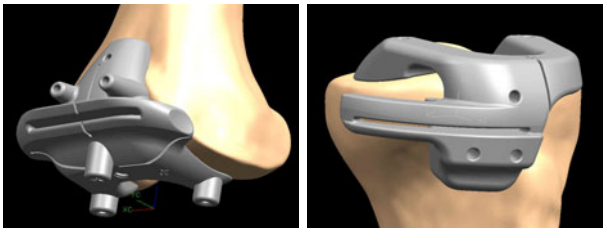

Figure 1. Femoral and tibial cutting block models

Table 1. Femoral Block Evaluation

MRI Protocol	Ease of Placement	Stability	Overall Score
A	3.67±0.58	3.33±0.58	3.33±0.58
B	3.80±1.09	3.60±1.34	3.60±1.51
C	4.00±0.71	4.20±1.30	4.20±1.30

Table 2. Tibial Block Evaluation

MRI Protocol	Ease of Placement	Stability	Overall Score
A	3.33±0.58	3.00±0	2.67±0.58
B	3.40±1.14	3.20±1.30	3.20±0.84
C	4.00±1.22	3.60±1.14	3.90±0.74

This study demonstrates the significance of MR imaging quality in ensuring reliable production and use of patient-matched disposable cutting blocks from a patient's MRI data. The potential benefits of this technology are consistent and accurate alignment of the implant with reduced OR time and reduced instrumentation.

References: 1. Hafez et al. Clinical Orthopedics and Related Research 444, 2006, 184-192

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