UKA Femur component sizing and bearing thickness affects ligament tension at different levels

Siggelkow E.[1], McBurney M.[2], Coleman M.[2], Jackson W.[3], Price A.[3], Troelsen A.[4], Bandi M.[1]
[1]Zimmer Switzerland Manufacturing GmbH, Winterthur, Switzerland; [2]Zimmer Biomet Inc., Warsaw, USA
[3]Nuffield Health Orthopaedic Centre, Oxford, UK, [4]Copenhagen University Hospital Hvidovre, Copenhagen, Denmark
eik.siggelkow@zimmerbiomet.com

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INTRODUCTION: Mobile bearing unicompartmental knee arthroplasty (UKA) shows excellent long-term results with a survival rate of 91% (20 years) [1]. However, there are factors which may result in reduced survival rates and/or patient dissatisfaction, including bearing dislocation, postoperative pain, and mid-flexion tightness, which may be interconnected. This study analyzed the effect of under- and over-sizing of medial partial femur components as well as the bearing thickness to resulting tension on the medial collateral ligament (MCL).

METHODS: Two specimen-specific and robotically-validated virtual biomechanics knee (VBK) models have been virtually implanted using different UKA femur component sizes (Oxford® Partial Knee, Zimmer Biomet, Warsaw, USA) combined with the matching bearing components and a suitable tibia component, utilizing the current surgical technique. Each VBK model was derived from CT and MRI scans of the specimens' femur, tibia, and fibula bone to generate a specimen-specific 3D geometry. The contributions of surrounding passive soft tissue of the capsule and cruciate and collateral ligaments were incorporated using a phenomenological ligament model validated against robot experimental testing [2]. The two VBK models were selected as they were determined to be in-between two femur component sizes. Furthermore, to evaluate the effect of the bone size on the resulting MCL ligament force, one VBK model (M1) represented a large and the second model (M2) a small bone model. Each of the VBK models received an 1) upsized femur and corresponding bearing component (M1: femur size Large, M2: femur size Small) and 2) a downsized femur and corresponding bearing component (M1: femur size Medium, M2: femur size X-Small). Additionally, the small-sized VBK model was analyzed with a 1mm thicker bearing for both femur size variations. For all models and component size variations, balancing analyses were performed to ensure the correct placement of the implanted models, and a passive path of flexion (PPF) was analyzed for which the forces of the MCL were tracked over a flexion range from extension to 140° flexion. The resulting tension on the MCL was compared for each VBK model variation.

RESULTS: For both the small- and large-sized VBK models, the implantation of the initial femur components shows a consistent, non-zero profile for the MCL force throughout the range of motion. When downsizing the femur and bearing component, the large VBK model resulted in a 25N increase in MCL force in mid-flexion (55°) (Figure 1, A). In comparison, the small size VBK model resulted in a 47N increase of the MCL force in mid-flexion for the downsized femur (Figure 1, B). Furthermore, when changing the bearing thickness from 4mm to 5mm for the small size VBK model, the increase in MCL force is 67N for the upsized femur component and 148N for the downsized femur component (Figure 1, C).

DISCUSSION: An ideal implantation is given when the femur component size matches perfectly the bone size, and the component placement is done in a balanced way which results in a consistent, non-zero MCL force profile and thus low risk of mid flexion tightness or dislocation. However, if the bone size is in between two femur component sizes the surgeon needs to decide for one. When maintaining similar implant position and alignment, a small size bone model is more sensitive to downsizing of the femur component, resulting in a larger MCL force increase when compared to the same change in a large size bone model. This behavior is even more pronounced when increasing the bearing thickness for the small size bone model. A combination of femur component downsizing and increasing bearing thickness doubled the MCL force increase. Downsizing the femur component decreases the femur radius, which results in an increase in mid-flexion material (Figure 2) and corresponding mid-flexion tightness of the joint. Therefore, when in-between sizes options for the femur component, upsizing the chosen size and choosing the correct bearing thickness may be considered to reduce mid-flexion tightness of the joint.

SIGNIFICANCE/CLINICAL RELEVANCE: Mid-flexion tightness is clinically reported for UKA (Oxford) implanted knee joints. The result of this study shows the relevance of the selection of the femur/bearing component size to the MCL tension which corresponds to the phenomenon of mid-flexion tightness and is potentially also connected to the mechanics of bearing dislocation.

REFERENCES: [1] Price et al., Clinical Orthopedics and Related Research, 2011, [2] Bandi, M. et al., ASME, 2012; [3] Hiranaka, T. et al., Orthopaedics & Traumatology: Surgery & Research, 2023

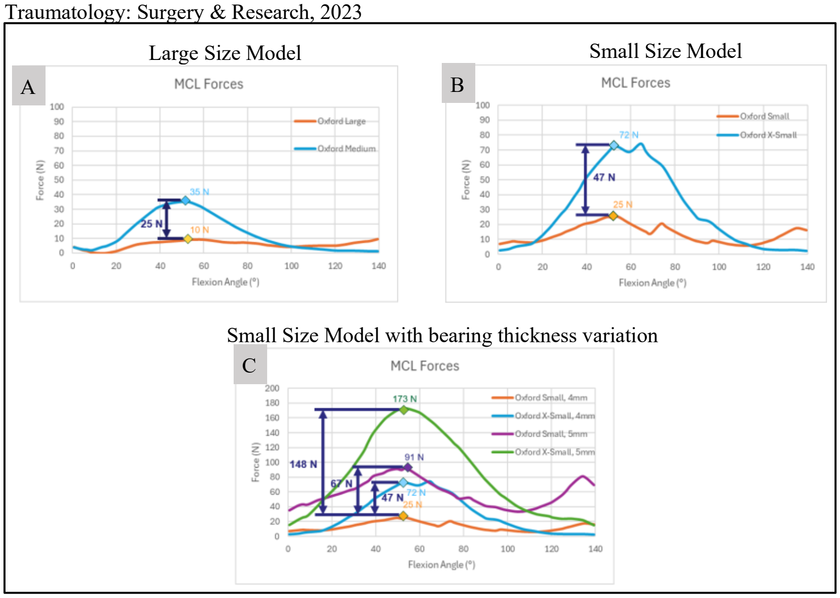

Figure 1: Comparison of MCL forces for both VBK models and the femur component size variation.

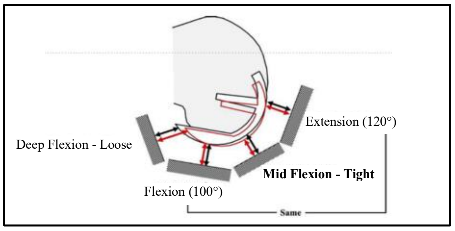

Figure 2: Geometric effect when downsizing (red)/ upsizing (black) a femur component [3].