Introduction: Total knee replacement has become a common surgical procedure aimed at pain reduction and restoration of normal knee function. Whilst numbers of TKAs in the U.S.A. are continually increasing, reaching an estimated 3.5M in 2030 [1], the current 10 year failure rates of up to 10% [2] will lead to an alarmingly high number of revision surgeries. Arthroplasty registers reveal that more than 50% of revisions are related to non-optimal joint biomechanics [3]. In order to improve the post-operative outcome, it is of critical importance to understand the mechanisms by which knee biomechanics are altered after TKA. An important factor seems to be the location of the joint line, since it has been clinically associated with knee pain and restricted function [4]. We hypothesize that the surgical elevation or depression of the joint line affects the joint contact forces (JCFs) at the knee, and incorrect implantation could therefore result in unnecessary revision of the joint. Until now, no biomechanical evaluation of these variations has been performed. The aim of this study, therefore, was to investigate the effect that variations in the joint line has on the tibio-femoral (T-F) and patello-femoral (P-F) joint contact forces during normal daily activities.

Materials and Methods: Virtual implantation: A TKA was virtually performed on the musculoskeletal models of 4 patients [5] (AMIRA, Mercury Computer Systems Inc., MA, USA). Component positioning was supervised by an experienced orthopaedic surgeon (GM).

Kinematic adaptation: Native lower limb kinematics for walking and stair climbing activities [5] was adapted to the postoperative situation using a geometric approach. Here, the T-F kinematics of the implant (Columbus UC, Aesculap, Tuttlingen, Germany) was described by rotations about the centers of the femoral articulating surfaces that were in contact with the conforming tibial component. While the knee flexion angles were kept consistent with the gait data, the locations of the femur and hip were adjusted to coincide with the implant kinematics.

Reconstruction of the joint line: Joint line depression was simulated by caudalising the femoral and tibial components, ensuring a constant limb length. Excessive resection of femoral bone, resulting in an elevation of the joint line, was simulated by cranialising the femoral component and either cranialising the tibial component or using a thicker insert. The joint line was altered from its anatomical location to ±15mm (Fig. 1).

Results: Elevating the joint line caused an increase in contact forces in the P-F joint as well as the T-F joints for both walking and stair climbing (Fig. 2). The P-F joint, however, experienced a relatively more pronounced increase in contact forces: During normal walking, a 10mm elevation of the joint line led to an increase in T-F contact forces of 0.09BW, but led to a corresponding increase of 0.25BW in the P-F joint. At the more extreme elevation of 15mm, increases of 0.14BW and 0.39BW were determined respectively.

During stair climbing, an elevated joint line caused a similar increase in contact forces in the T-F joint as walking. The P-F joint, on the other hand, experienced a significantly higher increase than during normal walking with 0.61BW for a 10mm and 0.99BW for a 15mm elevation. Depressing the joint line resulted in a decrease in contact forces for both joints and both activities. The largest change was again seen in the P-F joint. A 10mm depression of the joint line reduced the JCF by 0.21BW and 0.70BW for normal walking and stair climbing respectively and a 15mm depression produced a decrease of 0.31BW and 1.09BW.

Discussion: Although TKA surgery intends to reconstruct the anatomical joint line, which is known to play a role in the clinical outcome, lack of bone stock and surgical variation means that this is not always possible. Until now, the effect of elevating or depressing the joint line on the contact forces in the knee has been unknown. Using a validated musculoskeletal model [5] to simulate daily activities, we have demonstrated for the first time the effect that an altered or mal-positioned joint line has on the joint contact forces. Joint line elevations of a magnitude common in revision surgery [6], are likely to increase contact forces by more than half of a patient’s bodyweight (0.68BW at 10mm). Clinically, this knowledge establishes a fundamental understanding of the importance of surgical restoration of the joint line, but can also help explain clinical observations of its correlation to P-F pain, functional knee score, range of motion and mechanical problems [4].

This study has demonstrated that an overly careful tibial resection, and thus an increase in the joint line during TKA, will greatly increase forces in a patient’s P-F joint and may therefore be a direct cause of post operative pain. Furthermore, the observed reduction of JCFs provides a biomechanical basis for treatment of patella baja through depressing the joint line.

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References:

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