The Effect of Articulating Surface Features on Tibial Baseplate Micromotion

INTRODUCTION:
To obtain sufficient bone ingrowth and fixation, cementless tibial baseplates must maintain adequate initial stability following implantation. Previous studies have focused on quantifying initial stability as a function of baseplate fixation features. These features, however, may not be the only contributing factor to stability. The nature of the articulating surface of the knee design can also play a role. The previous studies typically disregarded these features by applying loads directly to the baseplate using a load applicator instead of a femoral component and insert. The objective of this study was to measure micromotion on one baseplate design as a part of a complete knee system. Two features of the articulating surface were varied to investigate their effect on micromotion: Insert thickness and cam/post engagement. Testing was performed using minimum and maximum insert thicknesses and at two static flexion angles that did and did not yield cam/post engagement.

METHODS:
A test model previously published by the authors was used in this study. A dual density polyurethane foam construct was developed to simulate the proximal tibia. The construct consists of an inner core of 12.5 pcf open cell foam to simulate cancellous bone, and an outer rim of 40 pcf closed cell foam to simulate cortical bone.

Six medium samples of a two cylindrical pegged baseplate were each mounted to a foam construct, and spheres attached to their medial, lateral, anterior, and posterior rims. Six LVDTs were mounted to each foam construct and arranged so that the plungers rested against the spheres. One LVDT was oriented superiorly/ inferiorly against the anterior, posterior, and one superiorly/ inferiorly against the posterior, to measure subsidence/lift off of the baseplate. Two LVDTs were oriented against the medial and two against the lateral sphere, with one LVDT oriented superiorly/ inferiorly and one oriented anteriorly/ posteriorly on each. These were used to measure subsidence/lift off against the motion of the baseplate.

A 25 mm PS insert was mounted to four of the baseplates, and a 9 mm PS insert to the other two, according to surgical protocol. Each component was mounted to a servohydraulic test machine (Figure 1). A loading profile representing a stair descent activity, adapted from Benson, et al., was applied to each insert/baseplate construct (Figure 2). All loads were applied to the baseplate through reactions of a PS femoral component articulating on the insert at a fixed flexion angle. Tests were run with the insert thickness/flexion angle combinations shown in Table 1. Zero degrees represented a flexion angle where cam/post engagement does not occur, and 72 degrees where it does occur. Compressive loads, anterior/posterior loads, and internal/external torques were varied as a function of the gait cycle. This loading profile is ideal as it represents a relatively high load activity that applies high shear forces to the tibial component at a low compressive load (at ~60% of gait cycle). The profile also involves reverse loading, which could be a cause of baseplate loosening in vivo.

Loading was applied for 2,000 cycles, while motions at each of the six LVDTs were recorded. Average peak to peak motion from each LVDT were calculated throughout the test, and averaged across samples. Comparisons were made via a t-test (α=0.05) between flexion angles for the components with 25 mm inserts, and between insert thicknesses for the components run at 72 degrees flexion.

RESULTS:
Figure 3 displays a comparison of the average peak to peak motion recorded at each LVDT with and without cam/post engagement (0 and 72 deg flexion, respectively). Results reveal higher motions at most locations when the cam is engaged with the post, with the differences being significant at the anterior and medial locations. Similarly, Figure 4 displays a comparison of motions across insert thicknesses. Results show substantially larger motions for the thicker insert at all LVDTs, with significant differences at the anterior, lateral, and posterior locations.

DISCUSSION:
Results of this study have shown that articulating surface features such as insert thickness and cam/post engagement can significantly affect micromotion of a tibial baseplate. Micromotion is caused by moments reacted at the bone interface. Thicker inserts can affect these moments by increasing the moment arm between the articulating surface where loads are generated and the bone interface. Similarly, cam/post engagement increases this moment arm as shear loads are reacted higher up on the post instead of at the articulating surface. Knee designs with early cam/post engagement are susceptible to imposing larger moments at the bone interface for longer periods of a gait cycle, increasing the potential for micromotion.

In conclusion, baseplate stability is not only a function of fixation features, but also articulating surface features. Micromotion should not be evaluated by testing the baseplate alone. The complete knee system needs to be evaluated in the worst-case condition for moments reacted at the bone interface.