Micromotion of Cementless Tibial Baseplates Under Physiological Loading Conditions  

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INTRODUCTION:
To obtain sufficient bone ingrowth and fixation, cementless tibial baseplates must maintain adequate initial stability following implantation. Previous studies have aimed at quantifying initial stability using simplified loading scenarios such as low cyclic compressive loads applied eccentrically to the tibia\(^1,2,3\), as well as isolated shear and torsional loads.\(^4\) However, few studies quantify micromotion under truly physiological loading conditions. The objective of this study is to develop a method to measure the micromotion of cementless baseplates during stair descent loading, and to use this method to evaluate the Duracon cruciform cementless baseplate (Stryker Orthopaedics, Mahwah, NJ).

METHODS:
A dual density polyurethane foam was developed to simulate the proximal tibia. The construct consists of an inner core of 12.5pcf open cell foam to simulate cancellous bone, and an outer rim of 40pcf closed cell foam to simulate cortical bone. Three Duracon cruciform baseplates were each mounted to a foam construct and six 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 sphere, and one superiorly/inferiorly against the posterior sphere, to measure subsidence/liftoff of the baseplate. Two LVDTs were oriented against the medial sphere, 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/liftoff and anterior/posterior motion of the baseplate.

The components were mounted to a servo-hydraulic test machine. A compressive load applied to the posterior third of the lateral condyle, along the A/P centerline. The load was cycled from 115 to 1150 N at 2 Hz for 100 cycles. Superior/inferior motion was monitored at the medial and lateral LVDTs throughout the test. Loading was then switched to the medial condyle, and the test was repeated. See Figure 1 for a photo of the test setup. Average peak to peak motion (i.e. recoverable motion) from each LVDT were calculated throughout the test, and averaged across samples.

A 25 mm posterior-stabilized (PS) polyethylene insert was then inserted according to surgical protocol. A loading profile representing a stair descent activity (Figure 2) was applied.\(^5\) All loads were applied via the Duracon PS femoral component articulating on the polyethylene insert at 45° flexion. Compressive loads, A/P loads, and torque loads 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 relatively low compressive load (at ~60% gait cycle). The profile also involves reverse loading, which could be a cause of baseplate loosening in-vivo. Loading was applied for 10,000 cycles. This represents 6 – 8 weeks of a stair descent activity,\(^5\) which is the approximate length of time to the initiation of bone ingrowth.\(^6\) Motions at each of the six LVDTs were monitored throughout the test. Average peak to peak motion from each LVDT were calculated throughout the test, and averaged across samples.

RESULTS:
Figure 3 displays a comparison of the average peak to peak motion recorded at the medial and lateral superior-inferior measuring (S/I) LVDTs across loading conditions (medial condyle loading, lateral condyle loading, and stair descent loading). Data is also shown for the additional four LVDTs recorded during the stair descent test. Results reveal the amount of S/I motion seen at the medial and lateral aspects of the baseplate are similar between the simplified and stair descent loading conditions. Substantially larger motions, of approximately twice the magnitude and higher, are seen in the S/I direction anteriorly and posteriorly, and in A/P shear medially and laterally, during stair descent loading. A particularly large amount of motion is seen in the S/I direction at the posterior location.

DISCUSSION:
The majority of previous studies on initial stability of cementless tibial baseplates have used simplified conditions that only load the medial and lateral condyles in compression, and only monitor motion at the medial and lateral aspects of the baseplate. This study shows that during physiologically relevant activities encompassing compressive, shear and torsional loads, substantially large motions can take place at other locations. Motions occur in both inferior/superior and anterior-posterior shear directions, with a particularly large amount seen at the posterior aspect of the baseplate. This is consistent with findings in literature showing only 27% bone ingrowth around baseplates after 15 months of implantation, with the least amount of ingrowth in the posterior location.\(^6\) To accurately assess the potential for bone ingrowth, future studies should focus on more clinically relevant loading conditions, and monitor motions in multiple locations around the periphery of the baseplate.

REFERENCES:

Acknowledgement: The authors would like to thank Laura Yanoso for her contribution and support throughout this study.

Figure 3: Mean Micromotion

Figure 2: Stair Descent Loading Profile\(^5\)

Figure 1: Test Setup

Simplified Load Setup
Stair Descent Setup

Poster No. 2231 • 55th Annual Meeting of the Orthopaedic Research Society