Tibial Baseplate Geometry Impacts Component Stability in Cementless Total Knee Arthroplasty

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INTRODUCTION: Initial stability of cementless total knee arthroplasty tibial components is necessary for bony ingrowth. The tray design features including peripheral pegs, keel and plate shape as well as surgical and patient factors that contribute to initial stability remain poorly understood. In this study, we investigated tibial component design factors that may affect implant stability using a biomechanical model.

METHODS: Physiological loading (level walking and stair descent) was robotically applied to cementless tibia trays implanted in foam tibia models (Figure 1). The models replicate cortical and cancellous bone material properties and the shape of the tibia. Three commercially available cementless tibia trays with keels and peripheral pegs from two different manufacturers (Table 1) were tested including symmetric, asymmetric and anatomically shaped tray profile. Maximum 3D micromotion was measured between the bone foam model and tibial tray at 10 locations using an optical measurement system.

RESULTS SECTION: The symmetric tibia tray had the greatest micromotion during level walking (229 ± 23 µm), followed by the asymmetric (205 ± 56 µm) and anatomic designs (84 ± 22 µm) (Figure 2). During stair descent the symmetric, asymmetric and anatomic designs saw maximum motion of 165 ± 17 µm, 151 ± 60 µm and 92 ± 17 µm, respectively. The anatomic tibia shape saw less 3D micromotion than the symmetric and asymmetric designs during walking ($p<0.05$) and less motion than the symmetric design during stair descent ($p<0.05$).

DISCUSSION: While the anatomic tibia tray saw equivalent micromotion across both activities, it experienced less micromotion than the other two designs. Interestingly, the symmetric and asymmetric trays saw greater micromotion during level walking compared to stair descent, despite the peak loads in stair descent being higher than walking. This study suggests tibial tray coverage afforded by an anatomic baseplate design improves tibial component stability during both level walking and stair descent activities.

SIGNIFICANCE/CLINICAL RELEVANCE: Cementless total knee arthroplasty requires a stable implant for boney ingrowth. This study evaluated the stability of a newly marketed cementless tibia tray compared to other clinically successful devices and showed increased stability with an anatomical shape.

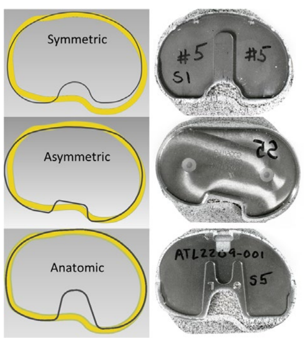

Figure 1: Left: Target placement for the three different designs of equivalent size in the design arm of this study. Right: Sample images of tibia constructs.

Table 1: Description of cementless trays tested for initial fixation.

Group	Sample Size	Material	Primary Fixation Feature	Secondary Fixation Feature	Articulating Surface	Plate Dimension* (mm)	Foam Dimension* (mm)
Symmetric	4	Printed Titanium	Keel	Cruciform Peripheral Pegs	Cruciate Stabilizing	M/L: 77 A/P: 52, 52	M/L: 80 A/P: 49, 56.9
Asymmetric	5	Ti + CSTi	Cruciform Keel	Round Peripheral Pegs	Congruent (Cruciate Retaining)	M/L: 79.3 A/P: 47.1, 52.6	M/L: 80 A/P: 49, 56.9
Anatomic	5	Printed Titanium	Keel	Square Peripheral Pegs	Cruciate Retaining	M/L: 79 A/P: 49.8, 56.1	M/L: 80 A/P: 49, 56.9

*Anterior/Posterior (A/P) Measurements listed lateral then medial. M/L=Medial/Lateral

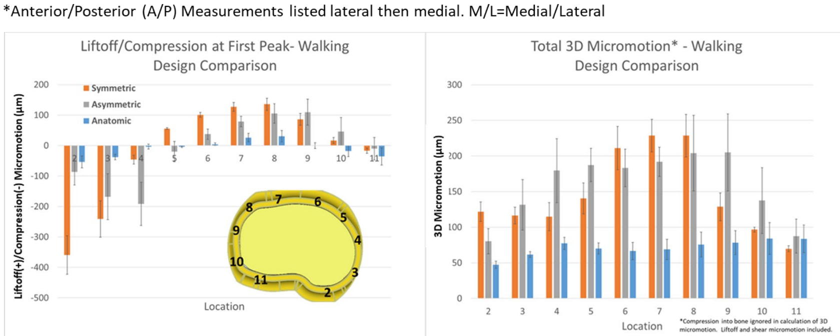

Figure 2: Left: Liftoff and compression at approximately the first compressive load peak at all 10 locations around the plate for the three different designs. Right: Total 3D micromotion including liftoff and shear micromotion. The 3D micromotion plot ignores any compression of the tray into the bone.