



Micromotion of Cementless Tibial Baseplates: Keels with Adjuvant Pegs Offer More Stability Than Pegs Alone



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ABSTRACT

Initial implant stability is crucial to cementless knee arthroplasty fixation. The objective of this study was to evaluate the stability of two baseplates with different fixation features: a monoblock porous tantalum baseplate featuring two hexagonal pegs alone, and a modular design featuring a keel with four adjuvant cruciform pegs. A physiologically relevant test method previously described was used to evaluate compression and liftoff of the baseplates during stair descent. The porous tantalum baseplate with dual-hex peg fixation experienced greater rocking motions and liftoff compared to the baseplate with a keel and adjuvant pegs. Liftoff and displacement motion is likely deleterious and may inhibit biological fixation due to the physical separation of the baseplate from the bone.

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Initial implant stability is crucial to achieving adequate biological fixation in cementless total knee arthroplasty (TKA). However, the optimal fixation design remains elusive. Previous biomechanical studies have aimed at quantifying initial stability using simplified loading scenarios [1–14]. A limitation across all these studies is that the loading was applied directly to the baseplate, as opposed to simulating the physiological loading that occurs from a femoral component articulating on an insert. Additionally, the load profiles were likely oversimplified, and did not accurately reflect the profiles of daily activities [1–14]. A physiologically relevant methodology simulating a stair descent activity, which incorporates torsion, shear and compression forces, was developed to evaluate tibial components and previously published [15]. The objective of this study was to use this methodology to evaluate the stability of two cementless baseplates with different fixation features: a monoblock baseplate featuring two 16-mm-long hexagonal pegs with established clinical success, and a modular design featuring a keel with four 9-mm-long cruciform pegs surrounding it.

Materials and Methods

Two cementless baseplate designs were evaluated in this study. The first was a monoblock baseplate made of porous tantalum featuring two 16-mm-long hexagonal pegs (NexGen Trabecular Metal™ Monoblock Tibial Component, Zimmer, Warsaw, IN). The second was a

modular design made of titanium featuring a keel with four 9-mm-long cruciform pegs surrounding it designed for supplemental fixation. The inferior surface of the tray and a small band at the superior portion of the keel and pegs were porous (Triathlon® Tritanium®, Stryker Orthopaedics, Mahwah, NJ). See Fig. 1 for photos of the two designs.

A test model previously published by the authors was used in this study [15]. To avoid the inter-specimen variability associated with cadaveric specimens, 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. The constructs were manufactured into a shape matching that of a 9-mm depth resection plane of a medium-sized tibial sawbone specimen (Pacific Research, Vashon, WA). The foam specimens designated for the full keel baseplates were prepped by punching the tibial punch tool into the cancellous core and drilling a 1/8" diameter hole for each cruciform peg. This yielded a 0.272-in.³ total volumetric interference of the four pegs and keel with the foam. Foam specimens for the dual-hex peg baseplates were prepped according to the surgical technique guide by drilling two 10.7-mm diameter holes into the cancellous bone analog, yielding a 0.018-in.³ volumetric interference of each peg with the foam. This also matches the amount of pressfit currently used clinically.

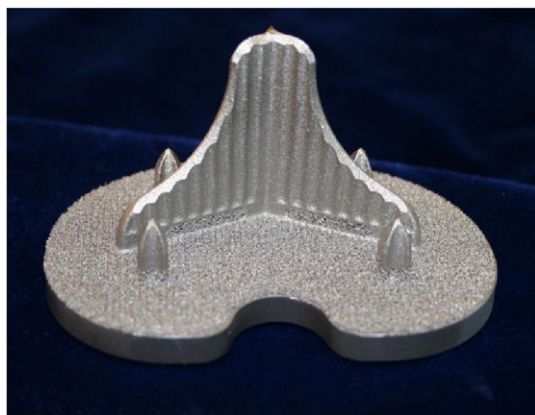
Seven samples of each baseplate were impacted into their respective foam constructs, and 0.375-in. diameter spheres attached to their medial, lateral, anterior, and posterior rims via dowel pins (Fig. 2). The tibial components were positioned such that each baseplate had cortical bone support under the anterior rim and posterolateral tibia, and cancellous support under the posterior medial tibial plateau (Fig. 2). LVDTs (linear variable differential

The Conflict of Interest statement associated with this article can be found at <http://dx.doi.org/10.1016/j.arth.2014.02.016>.

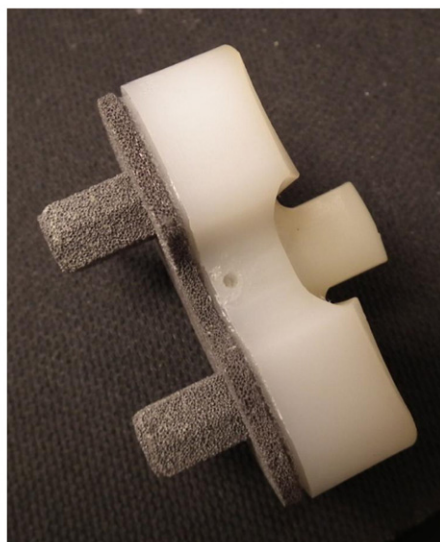
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Keel with Four Pegs Device



Dual Hexonagel Peg Device

Fig. 1. Devices tested.

transformers) were then mounted to the foam constructs and arranged to measure compression/liftoff motion at each sphere.

Mating 16-mm PS inserts were mounted to the modular baseplate according to surgical protocol (the dual-hex peg monoblock design featured a 17-mm PS insert). Each construct was then rigidly clamped to the anterior/posterior actuator of a servohydraulic test machine

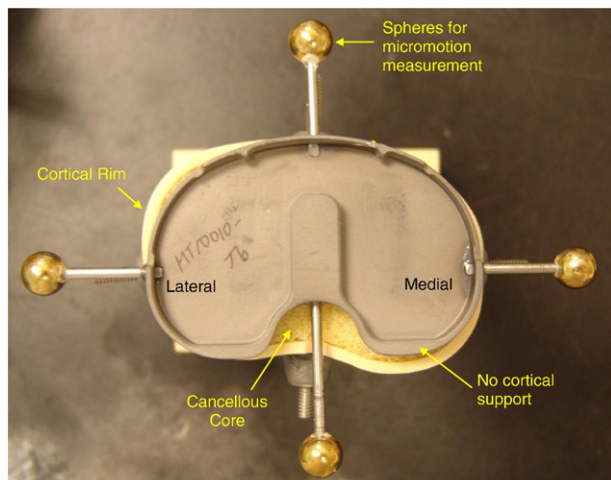


Fig. 2. Baseplate alignment/sphere locations.

(Fig. 3). A mating femoral component of each design was mounted to the axial actuator using a fixture that allowed unrestricted motion in the coronal plane and the flexion angle to be locked. A loading profile representing a stair descent activity, adapted from Benson et al. [15,16], was applied to the constructs (Fig. 4). 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% gait cycle). The profile also involves reverse loading, which could be a cause of baseplate loosening in vivo. Due to limitations of the test machine, the femoral component could not be actively flexed. Testing was run at a fixed flexion of 72°, which represents an average angle at which the peak anterior/posterior shear load occurs at a minimal compressive load, simulating a worst-case scenario and increasing the potential for rocking motion between the baseplate and simulated bone [16]. This angle is also deep enough to ensure cam/post engagement on both designs tested.

Loading was applied at a rate of 0.25 Hz for 10,000 cycles. This represents 6–8 weeks of a stair descent activity [17], which is the approximate length of time to the initiation of biological fixation [18,19]. Motions at each of the six LVDTs were monitored throughout the test at a rate of 25 Hz.

Data analysis involved separating the motions measured at each LVDT into peak compression of the tray into the foam vs. peak liftoff from the foam. The average of these peaks was calculated over three cycles at the end of the test for each sample, and then averaged across samples. Comparisons between designs were made via an unpaired *t*-test with $\alpha = 0.05$.

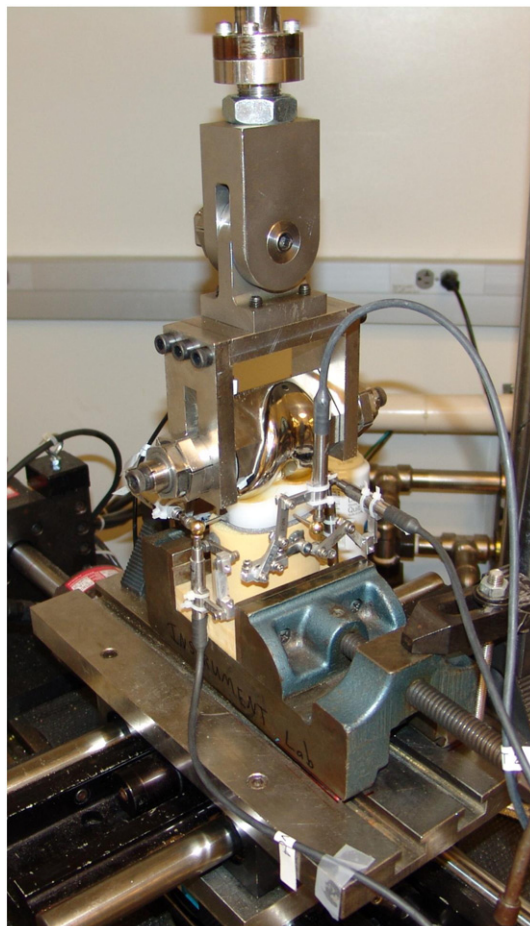


Fig. 3. Test setup.

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