

Impact of Total ankle Replacement Tibial Implant Choice on Time-Zero Micromotion

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DISCLOSURES: Jeffrey Hoffman (N), Jensen Henry(1; Stryker Inc., Arthritis Foundation. 6; Stryker Inc.. 8; Foot and Ankle Specialist.), Ricardo Villar (N), Sungjung Kim (N), Constantine Demtracopoulos (1; Livatec, Exactech Inc.. 3B; Arthrex Inc, Exactech Inc., MedShape Inc., Responsive Arthroscopy, Restor3d, SIMULATE Technologies LLC, Treace Medical. 4; HS2. 8; Foot and Ankle International. 9; American Orthopedic Foot and Ankle Society.), Brett Steineman (N)

INTRODUCTION: Total Ankle Arthroplasty (TAA) has rapidly expanded as a treatment of post-traumatic ankle arthritis over the past 20 years. However, despite large improvements in post-surgical outcomes for patients, survivorship for implants still lags the rates demonstrated in knee and hip implants [1]. The most common cause of loosening of the implant comes from aseptic loosening of the implant, which can occur because of excessive micromotion at the bone-implant interface, resulting in a lack of osseointegration. Despite being commonly used in the market, low profile implants have demonstrated relatively low 5-year survivorship rates compared to other joints [2]. Conversely, stemmed implants have shown higher survivorship rates at mid-term follow-up but require more bone resection. Therefore, our objective in this study was to quantify the amount of bone-implant micromotion present for both implant types during gait.

METHODS: Ten matched pairs of lower extremity specimens (6 males, 4 females; age: 48 ± 11.2 years) performed stance phase simulations using previously validated six-degree of freedom robot [3]. The simulator works by rotating a force plate around a stationary tibia, while linear actuators apply physiologic muscle forces at the specific instance which are active during stance phase of gait [4]. The trajectory of the force plate around the foot and the forces of the Achilles and tibialis anterior tendons were optimized using an iterative learning control algorithm using fuzzy logic [5]. Matched pairs were randomized to receive either a low-profile tibial implant (Infinity; Stryker Inc.; Kalamazoo, MI) or a stemmed implant (Inbone II; Strkyer; Kalamazoo, MI). Each specimen was then implanted with their assigned implant, according to manufacturer specifications, by an attending orthopaedic surgeon. A digital image correlation (DIC) camera system (Aramis; Trillion Inc.; King of Prussia, PA) was used to track the motion of reflective markers attached to the anterior surface of the distal tibia and tibial implant during simulations. The position of the reflective markers on the tibia and implant were registered relative to borosilicate glass balls, which were attached to the medial malleolus, by using a coordinate measurement machine (GageMax; FARO; Lake Mary, FL). Geometries of the tibia, tibial implant, and borosilicate spheres were segmented and smoothed from post-TAA implantation CT scans and exported into reverse engineering software. Rigid body transformations of the tibia and implant were each then calculated using DIC motion data to determine the motion of the implant relative to the tibial bone-implant surface at each point during the simulation. Primary outcome measures for each specimen were the maximum peak micromotion which occurred during stance phase, and the percentage of the implant surface area which had micromotion values over the critical threshold of $150 \mu\text{m}$. Paired t-tests were used to determine the implant fixation type which had the higher peak micromotion and higher percentage of the implant over the critical threshold during stance phase.

RESULTS: Low-profile implants consistently demonstrated higher values of micromotion in comparison to their matched pair which received a stemmed implant. Low-profile implants demonstrated significantly higher peak micromotion ($p < 0.001$), with an average peak of $333 \mu\text{m} \pm 139 \mu\text{m}$ in low-profile implants in comparison to $183 \mu\text{m} \pm 142 \mu\text{m}$ in stemmed implants. At the point of peak micromotion, the percentage of the implant surface area that had moved more than the $150 \mu\text{m}$ threshold for bone in growth was an average of $52\% \pm 27\%$ in the low-profile implants compared to $17\% \pm 30\%$ in the stemmed implants ($p < 0.001$). Higher micromotion values typically occurred on the posterior portion of the implant in low-profile implants at peak, while higher values occurred on the tip of the stem for the stemmed implants.

DISCUSSION: The results of this study demonstrated that stemmed implants had consistently lower peak micromotion values compared to low-profile implants. These differences coincide with previous studies, which have shown that the failure rate of low-profile implants exceed 5% at mid-term follow-up [2], while stemmed implants have been shown to reduce the odds of tibial failure by 95% [6]. An important finding was the difference in micromotion observed in low-profile implants in which the micromotion peak was located on the posterior aspect of the implant, indicating a potential “rocking” motion in the sagittal plane during stance.

CLINICAL RELEVANCE: The results of this study provide valuable insight into the effects of fixation design on the risk of aseptic loosening of tibial components. These results can be considered by clinicians in decision-making of implant type in TAA patients.

REFERENCES: 1. Kooner et al., 2021; 2. Cody et al., 2025; 3. Baxter et al., 2016; 4. Aubin et al. 2012; 5. Whittaker et al, 2011

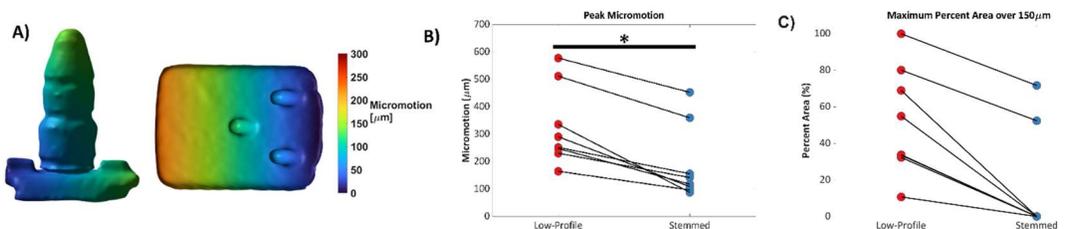


Figure 1: (A) Three-dimensional heatmaps of the micromotion distribution at the point of peak micromotion during stance. (B) Peak Micromotion values during stance for both the low-profile (Red) and stemmed (blue) implant types. Matched pairs are connected by a black line. (*) denotes a significant difference in peak micromotion between the two conditions during stance phase. (C) Percent of the implant over the $150 \mu\text{m}$ critical threshold for osseointegration at the point of peak micromotion. Matched pairs are connected by a black line.

