DEPENDENCE OF TOTAL ANKLE TIBIAL BASEPLATE STABILITY UPON BONE DENSITY

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Introduction

- Success of uncemented total ankle replacement (TAR) is primarily a function of initial implant stability.
- Implant-bone micromotions < ~50 µm promote bone ingrowth, while those > ~150 µm promote fibrous ingrowth.[1,2]
- Tibial implant design fixation features play a critical role in determining early stability.
- Fixation is supplemented with retention of medial/lateral bone sidewalls and interference fit.
- Tibial component stability likely also influenced by regional bone density.
- This study reports preliminary findings on how patient-specific bone density effects bone-implant micromotions.

Objective

Investigate how bone density affects implant-bone micromotion between the tibial component of a specific TAR design and the distal tibia.

Methods

- Finite element analysis (FEA) was used to evaluate micromotions of the tibial component of a TAR system.
- TAR system virtually implanted into computer models of two patients with end-stage ankle arthritis.
- Patients were selected for having similarly sized tibias (patient body weights of 61 and 56 kg, respectively).
- Clear differences in bone density profiles were observed in the affected ankles.
- Tibia models generated from CT scans, with bone density-based inhomogeneous material distribution assigned (Figure 1) to model bone compaction (plastic deformation) with interference fit.[3]
- Tibial component of implant modeled as titanium alloy material.
- Two different fixation cases modeled:
  (1) Retained sidewalls + line-to line fit
  (2) Retained sidewalls + 50 µm press-fit
- FEA performed using body weight-scaled kinetic profiles representing the stance phase of gait, applied to distal implant surface while proximal tibia held fixed.[4]
- Press-fit was simulated prior to gait.
- Micromotions defined as displacement difference between implant-bone closest node pairs.

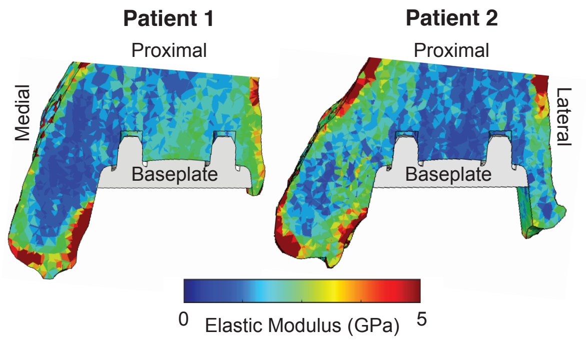

Figure 1: Coronal cross-section view of elastic modulus assignment through center of baseplate pegs

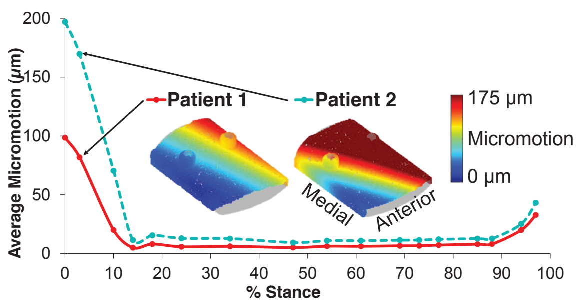

Figure 2: Micromotion during stance with sidewalls+line-to-line fit

Results

- For sidewalls + line-to-line fit fixation, micromotions were largest early and late in the stance phase of gait (Figure 2), with largest micromotions observed at heel strike (0% stance).
- Dorsiflexion moment dominates in early stance with minimal proximally-directed forces, stressing the anterior edge of the implant, resulting in relatively large posterior/lateral gapping (Figure 2, inset).
- Observed difference in micromotion between the two patients correlates with differences in bone quality at the tibia contact surface, particularly around the implant pegs (Figure 1).
- When interference press-fit was modeled, differences in micromotion largely disappeared (Figure 3), as adequate bone compaction was generated around interference regions with sufficient bone quality to resist motion (Figure 4).

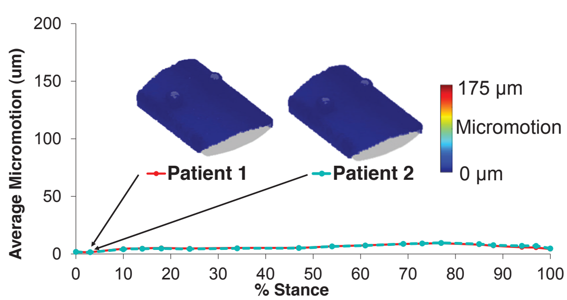

Figure 3: Micromotion during stance with sidewalls+press-fit

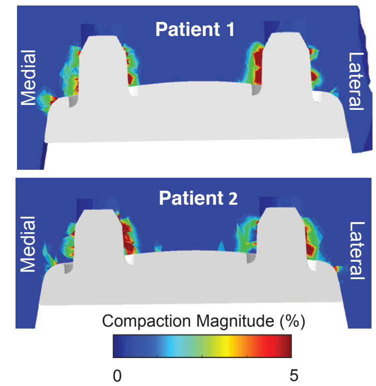

Figure 4: Compacted bone after press-fit

Discussion

- Findings suggest that patient-specific differences in bone density impact implant behavior.
- Differences due to bone quality were diminished when interference fit was modeled.
- Interference press-fit has dominant effect on implant stability
- Bone compaction (plastic deformation) from the interference fit likely explains the limited micromotion, as the forces generated from press-fit would prevent implant motion.

Significance

- This study presents novel insights into the effect of TAR fixation features and the associated micromotion at the implant-bone interface in patients with varying distal tibia bone density.
- Further investigation needed for a more comprehensive understanding, but we believe this shows the importance of bone quality and interference press-fit in stability of uncemented TAR implants.

Acknowledgements

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References

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