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Evaluating the Initial Stability in Cementless Patellar Implant During a Single-Leg Lunge

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Introduction

Initial stability of cementless implants after total knee arthroplasty is crucial to establish bony ingrowth into the porous interface surface and maintain long-term fixation [1]. Previous studies mainly focused on quantifying tibial micromotion via experimental or computational models [2,3]. However, few have investigated patellar implant micromotion. The goal of this study was to investigate cementless patellar implant micromotion under implant-specific loading conditions and assess the initial fixation stability for different patellar implant designs.

Methods

Ten different cementless patellar prostheses with variations in articulating surfaces and sizes were implanted onto synthetic bones machined from sheets of 12.5 lb/ft^3 closed-cell polyurethane foam (Sawbones, Pacific Research Lab) (Fig. 1). All implants had three cylindrical pegs coated with porous titanium for fixation to the host bone. The experimental simulation included seven variations of a single-leg lunge activity. In the experimental simulations, the anterior-posterior and medial-lateral axis were force controlled and displacement controlled in other degrees of freedom [4]. Bone-implant micromotion was measured using digital image correlation with marker pairs on either side of the bone-implant interface. Finite element (FE) models of the constructs were created, verified against the experimental measurements, and subsequently evaluated in a design-of-experiment fashion to quantify the influence of implant shape, patellar size, and patella contact mechanics on implant interface micromotion. Micromotion on the implant-bone interface surfaces was computed based on changes in distance between each node on the implant fixation surface and the closest node on the corresponding bone mesh over the cycle for each model configuration.

Results

Positive correlations between FE surface marker displacements and interface micromotions were observed, ranging from $r^2 = 0.25$ to 0.95. These correlations were strongest for the smallest patella sizes (Fig. 2). Peak interface micromotions consistently occurred on the pegs and not on the plateau of the implant-bone interface. For six of the seven loading conditions, the largest compressive interface micromotions were observed on the 31-mm symmetric patella which had the smallest size among the implants studied, ranging from 100~174µm (Fig. 3). The predicted peak compressive interface micromotions for implants with different articulating surfaces were on average 95.5µm (medialized dome), 96.8µm (anatomic), 126.0µm (symmetric dome), and 73.0µm (asymmetric dome).

Conclusion

The peak interface micromotions were primarily influenced by implant size, possibly due to smaller contact areas and corresponding deformation of the underlying foam bone in smaller implants. The impact of variation in the articulating surfaces was less significant but should still be considered in pre-clinical evaluations. The relative displacements measured between marker pairs across the exposed bone-implant interface were correlated with the actual micromotions on the interfacing surfaces, but were larger in magnitude, indicating the necessity for computational modeling to evaluate cementless patellar implant fixation. All patella evaluated in this study exhibited interface micromotions within the threshold necessary for osteointegration.

Acknowledgements

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References

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2. Crook, et al., J Arthroplasty. 2017
3. Fitzpatrick, et al., J Biomechanics. 2016
4. Navacchia, et al., J Mech Behav Biomed Mat. 2018

Figures

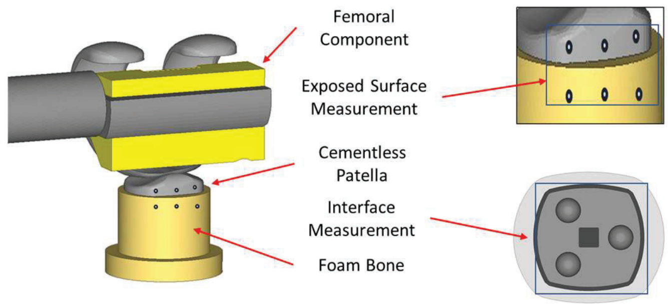

Figure 1: Computational model and two measurements in this study.

Figure 1

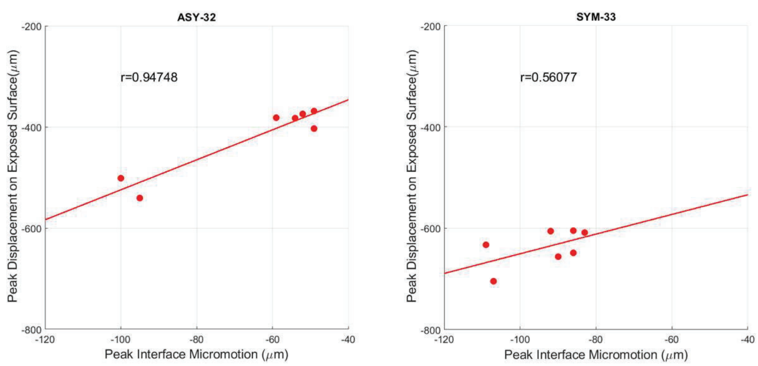

Figure 2. The correlation between peak relative displacements on the exposed surface and the peak implant-bone micromotion for two representative implants (32 asymmetric dome and 33 symmetric dome).

Figure 2

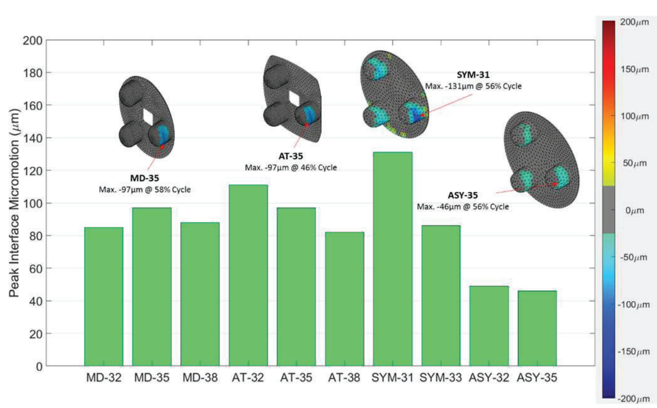

Figure 3. Predicted compressive peak interface micromotion under the neutral loading case. Patella implant-bone interface micromotions at the frame representing the largest compressive micromotion under the neutral loading case (inset).

Figure 3