Influence of Physiological Loading Following Intra-Operative Lipid/Marrow Infiltration and Intra-Operative Motions upon Tibial Implant Fixation

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INTRODUCTION: Aseptic loosening is a leading cause for revision in total knee replacement (TKR). As such, it is of particular interest for researchers to investigate the conditions necessary to reproduce this scenario in-vitro. Previous studies have shown that lipid/marrow infiltration (LMI) during implantation may significantly reduce fixation of tibial implants to bone analogs [1,2]. It is not well understood what the effect of physiological loading may have on fixation of tibial implants subsequent to LMI affected cementation. This study aims to investigate this effect through determination of fixation failure load.

METHODS: Three commercially available fixed bearing tibial implant designs were investigated in this study: ATTUNE®, PFC SIGMA® CoCr, and ATTUNE® S+. Samples were first prepared for a baseline testing to determine what the LMI fixation failure load was without physiological loading. Following the method described by Maag et al [1] tibial implants were cemented in a bone analog with 2 mL of bone marrow in the distal cavity and an additional reservoir of lipid adjacent to the posterior edge of the implant. Tibial implant constructs were then subjected to intra-operative ROM/stability evaluation using an AMTI VIVO simulator, followed by a hyperextension activity until 15 minutes of cement curing time, and finally 3 additional ROM/stability evaluations were performed. The baseline samples were then mechanically tested for fixation failure load.

Implant specific physiological loading was determined using telemetric tibial implant data from Orthoload [3] and applying it to a validated finite element lower limb model developed by the University of Denver [4]. Two high demand activities were selected for the loading section of this study: step down (SD) and deep knee bend (DKB). Using the lower limb model, 6 degree of freedom (DOF) kinetics and kinematics for each activity were determined for each posterior stabilized (PS) implant design. These implant specific loading parameters were then applied to the three tibial implant designs prepared as described above for baseline samples. Using an AMTI VIVO simulator each sample was subjected to 50,000 DKB cycles and 120,000 SD cycles at 0.8 Hz in series; equating the approximately 2 years of physiological activity. After physiological loading the samples were tested for fixation failure load.

RESULTS: Baseline LMI fixation failure loads of ATTUNE®, PFC SIGMA® CoCr, ATTUNE® S+ were measured to be 2505 N (n=6), 2184 N (n=5), and 5162 N (n=6), respectively. Following physiological DKB and SD loading fixation loads were measured to be 1869 N (n=9), 1540 N (n=9), and 5278 N (n=9), respectively. This demonstrated no statistically significant difference between before and after physiological loading ($p>0.05$), while showing a significant difference between ATTUNE® S+ and ATTUNE® as well as ATTUNE® S+ and PFC SIGMA® CoCr ($p<0.05$) (Figure 1).

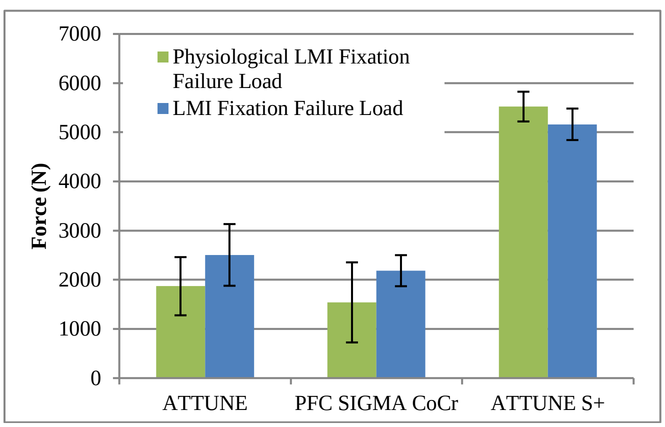

Figure 1. Fixation failure loads

Implant Design	Fixation Failure Load with Physiological LMI (N)	Fixation Failure Load with LMI (N)	EFORT 2017 Fixation Failure with LMI (N)	EFORT 2017 Fixation Failure without LMI (N)
ATTUNE®	1869 ± 591 (n=9)	2505 ± 627 (n=6)	2624	4670
PFC SIGMA® CoCr	1540 ± 814 (n=9)	2184 ± 316 (n=5)	1913	5649
ATTUNE® S+	5278 ± 378 (n=9)	5162 ± 320 (n=6)	3870	7206

Table 1. Comparison of EFORT and study data

DISCUSSION: When comparing data produced in this study to that of Maag et. al. [1] (Table 1), it is seen that the largest drop in fixation load is due to the introduction of LMI and intra-operative motions. This study shows there is no significant change in fixation failure load with the addition of subsequent physiological loading.

SIGNIFICANCE / CLINICAL RELEVANCE: Establishing in vitro protocols to replicate and better understand how surgical technique and clinical conditions affect long term performance with TKR are vital for making improvements to implant design and surgical techniques in orthopaedics.

REFERENCES:
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