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Cortical Bone Viscoelasticity has Diminishing Effects on Contact Pressure in Press-Fit Stems but Does Not Jeopardize Implant Stability

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CORTICAL BONE VISCOELASTICITY HAS DIMINISHING EFFECTS ON CONTACT PRESSURE IN PRESS-FIT STEMS BUT DOES NOT JEOPARDIZE IMPLANT STABILITY

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INTRODUCTION: Cementless implants achieve *long-term* fixation and consequent clinical stability primarily via biologic means – bony ingrowth into a porous-coated intramedullary implant surface. The adequacy of this biologic fixation depends upon numerous factors, including the initial or *short-term* fixation of the implant with respect to the adjacent bone (1,5,6). *Short-term* fixation refers to the post-operative limitation of relative motion between implant surface and the adjacent bone. Micromotion may be limited by utilizing a rough implant coating in concert with a distal stem press-fit. However, the holding power of the press-fit over time is dependent upon the viscoelastic nature of cortical bone (2). The objective of this study was to experimentally evaluate the effect of transverse cortical bone viscoelasticity on initial diaphyseal fixation of an implant for various degrees of press-fit (diametral interference (δ)) and surface coating. It was hypothesized that viscoelastic relaxation increases with press-fit amount. It was also hypothesized that if bone was stressed above a certain level during press-fit, implant fixation would be reduced.

METHODS: Eleven femoral pairs were utilized in this study (females 63.1±3.9, males 53.6±8.9). The target cortical index range, as calculated from anterior-posterior x-ray films was 40-60%, which was also representative of the hip replacement population (3,4). The right and left femurs were cut into three 4 cm long diaphyseal bone sections that were reamed until "chatter" (resistance to reaming from cortical bone) was felt. After reaming, a cylindrical CoCrMo alloy intramedullary test specimen (DePuy, A Johnson and Johnson Company) was selected that corresponded to line-to-line (same size stem as ream), 0.5 mm press-fit (a stem with a diameter 0.5 mm larger than the reamer) and a 1.0 mm press-fit (a stem with a diameter of 1.0 mm larger than the reamer). The actual press-fit was then calculated form the difference between the reamer diameter and the measured stem diameter. Three stem surface conditions were manufactured including 20 grit, small bead coating (60/80 mesh Porocoat porous coating) and large bead coating (24/35 two layer coating). With the bone held in place on an annular loading platform, the test specimens were inserted into the bone segments using standard operating room tools and procedures. Once inserted, the loading platform was placed between the cross-heads of a servo-mechanical testing machine (Materials Testing System, Minneapolis, MN) and loaded under stroke control at 1 mm/min. Actuator load and deflection were recorded and plotted for determining the push-out load. The push-out load was defined as the maximum load attained prior to slipping of the stem within the canal. The push-out load was determined for specimens at time=0 hours ($P_{t=0}$) and after 24 hours ($P_{t=24}$) of soaking in a physiological bath. From these two quantities, the viscoelastic Load Radio was found as Load Ratio = P_0/P_{24}. The Load Ratio was a measure of the viscoelastic effect on the "holding strength" of the stems. Statistical analysis was performed using JMP (SAS Institute, Cary, NC) and significance was set at $p<0.05$.

RESULTS: Results indicated that there was no significant relationship between push-out loads and press-fit at t=0 and t=24 hours (Figure 1). However, a nonlinear regression analysis of the pooled Load Ratio versus press-fit data indicated a significant ($p<0.0002$, $r^2 = 0.43$) quadratic relationship (Figure 2). Therefore, more relaxation occurred between t=0 and t=24 hours resulting in less push-out load as press-fit increased. The analysis also indicated that small bead coated (i.e. Porocoat) stems have significantly greater push-out loads at t=0 hours ($p<0.01$) and t=24 hours ($p<0.04$) compared to large bead coated stems. The small bead coated stems also demonstrated greater push-out loads than the 20 grit stems but the difference did not reach statistical significance.

DISCUSSION: Results from experiments showed that relaxation significantly increased with press-fit, i.e. there was a greater reduction in push-out loads at higher press-fit as hypothesized. It was found that stability of the stem was not related to press-fit amount, indicating that after achieving press-fit, no additional gains or losses in stability were obtained by increasing press-fit, contradicting our second hypothesis. In finite element analysis conducted in our lab, results suggest an implant-bone interference fit threshold (~δ=0.10mm) above which there would be no advantage in short-term push-out strength. This is indicative of an interference "threshold;" that is, a value of interference above which no significant benefit in terms of holding power is obtained. The results of this study showed that cortical bone viscoelasticity in the transverse plane of the diaphyseal femur has a diminishing effect on the contact pressure between the endosteal bone surface and the press-fit implant. This effect becomes significantly more pronounced as press-fit increases. However, there was no significant relationship between press-fit amount and push-out load. Therefore, for a particular implant size, there is a degree of press-fit beyond which no additional gains or losses in *short-term* fixation are realized. Additional study into this phenomena is warranted in view of the clinical implications.

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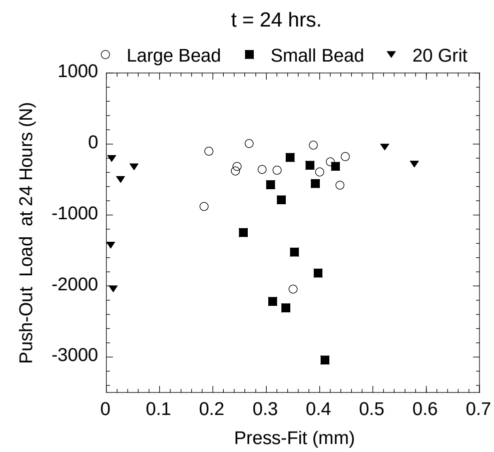

Figure 1. Push-out load vs. press-fit at t=24 hrs.

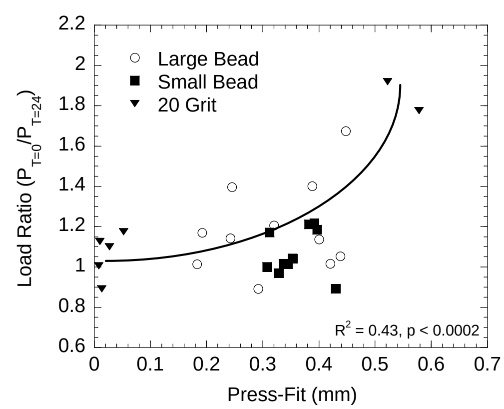

Figure 2. Load Ratio plotted vs. press-fit.