Evaluation of Metaphyseal Sleeves as a Fixation Strategy for Distal Femur Replacement: A Biomechanical Study

Christopher Leibold, Jared M Newman, Miguel A Diaz, Pablo Sanchez-Urgelles, Peter Simon, Thomas L Bernasek

INTRODUCTION: Distal femoral replacement (DFR) is a salvage procedure performed in the setting of severe bone loss, non-reconstructable fracture, or following tumor resection with highly variable implant survivorship. The use of metaphyseal sleeves in revision total knee arthroplasty has been shown to improve survivorship and decrease rates of aseptic loosening. This biomechanical investigation evaluates and compares the performance and relative micromotion across the implant-bone interface for cementless DFR utilizing a metaphyseal sleeve only and the use of cerclage cables with metaphyseal sleeve. It was hypothesized that the cerclage cables will improve the initial stability and biomechanical performance when compared to the cementless DFR with metaphyseal sleeve only.

METHODS: A total of 14 cadaveric femurs were equally divided into two groups: 1) cementless DFR with sleeve; 2) cementless DFR with sleeve and two cerclage cables. Dynamic loading of the femur was performed with the femur at 14° flexion and inverted where the femoral component was in contact with a matched rotating platform tibial component (Figure 1). Samples were sprayed with a stochastic pattern to allow the measurements of micromotion with the use of digital imaging correlation (ARAMIS; GOM) (Figure 2). Each sample ran 10,000 cycles at a frequency of 1 Hz with an increment in compressive load every 2,000 cycles until reaching last load step (LS) of 2.5 times body weight or failure (≥10mm of stem displacement and/or fracture). Thereafter, samples that survived were simultaneously loaded with 2030 N in axial load and internal-external moment of 7 N*m to analyze torsional stiffness. The Mann Whitney U-test was performed to assess differences in construct stiffness, displacement and sleeve micromotion. Observations on failure mode and cycles to failure were noted.

RESULTS:

Group 2 had significantly higher stiffness when compared to Group 1 ($p=.0213$) suggesting the addition of cerclage cables significantly increased the stiffness compared to the sleeve only. Both Group 1 and Group 2 had comparable displacements early in the loading phase, however, both had a substantial increase during LS3. Similarly, micromotion followed similar outcomes and both were below 150 µm threshold for the first two load steps. Overall, Group 1 had significantly more displacement compared to Group 2 ($p=0.039$). Moreover, 71% of the Group 2 samples survived through to the last load step compared to the 28% of Group 1 samples, where Group 1 samples failed due to fractures (Figure 3). Additionally, Group 2 was rotationally more stable than Group 1 suggesting the cerclage cables improved the torsional stiffness ($p=0.045$).

DISCUSSION AND CONCLUSION:

Modern implant designs now allow for coupling of DFRs and metaphyseal sleeves through a Morse taper. Aseptic loosening is a major concern given the significant torsional stresses encountered using a constrained prosthesis and represents one of the most common long-term complications following endoprosthetic reconstruction. The use of metaphyseal sleeves with uncemented DFRs appear to have adequate initial stability and is improved with the use of cerclage cables. A reduction in stability (increase in micromotion) was observed as the cycles and loading conditions increased. The use of cerclage cable with cementless DFR metaphyseal sleeve provided increased axial stiffness, torsional stiffness and improved initial stability compared to cementless DFR metaphyseal sleeve only.

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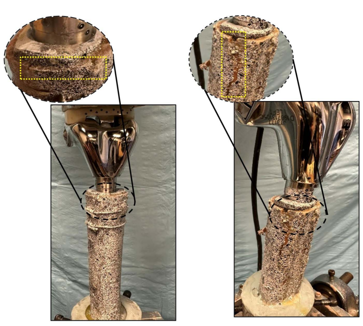

Figure 3. Illustration of study group failure modes

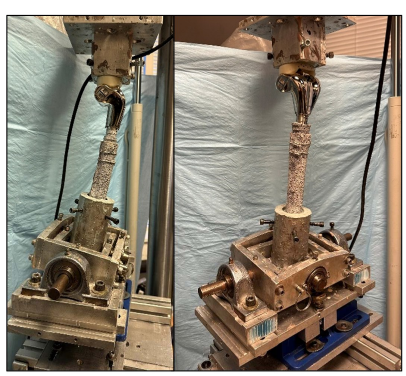

Figure 1. Biomechanical Testing setup

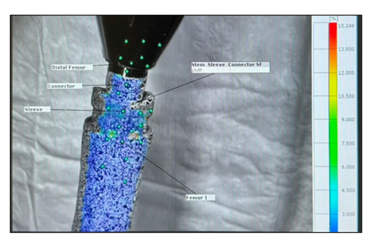

Figure 2. Example of surface registration and point creation in DIC software