Structural Dynamics and Acoustic Systems Laboratory
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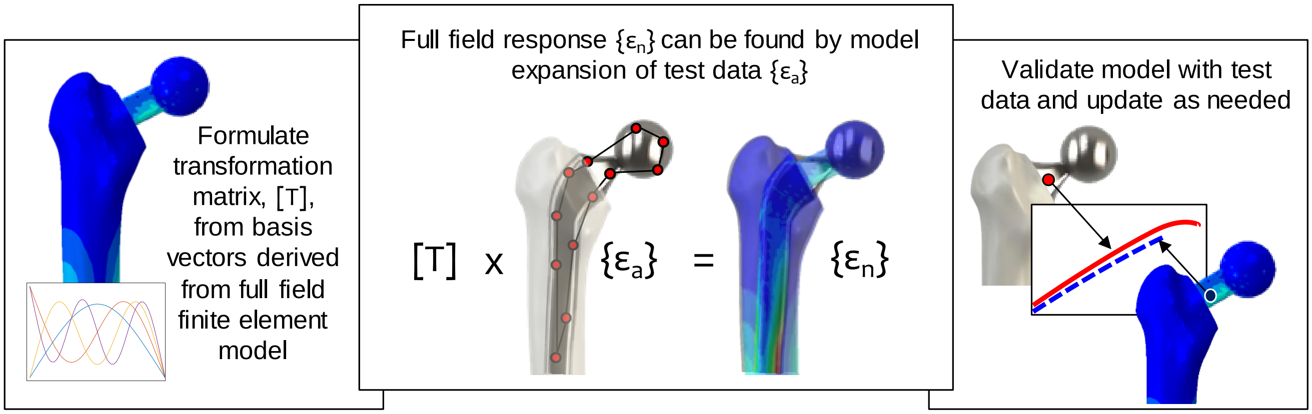
Modeling and Test Methodologies for Monitoring Femoral Implant Insertion during Cementless Total Hip Arthroplasty



Cementless hip replacement allows the bone to heal directly to the prosthesis and is often a good option for clients with relatively healthy bone tissue. After removing the femoral head, the surgeon reams the femur to an area slightly smaller than the implant and then press fits the implant into the femoral canal. Residual stresses from the press fit are required for implant stability and the magnitude of these stresses is critical. An implant is properly seated when the stresses are high enough to prevent micromotion of the implant but low enough to avoid femoral fracture. No device exists to objectively assess implant stability intraoperatively. Surgeons must rely solely on clinical experience to determine proper seating. The aim of this work is to develop a methodology involving data-driven analytical models that can be used in the prediction of bone stress/strain introduced by femoral implant insertion during cementless total hip arthroplasty.

Cementless femoral stem implantation can be thought of as a complex contact analysis problem with both static and dynamic effects. Dynamic effects include transient structural and acoustic vibrations that result from striking the implant with a surgical mallet, while static effects involve the contact stresses/strains that hold the implant in place. Non-linearities arise as the implant translates deeper into the broached femoral canal, changing the boundary stiffness at the bone-implant interface. This work involves development of finite element models to simulate the press fit process followed by formulation of a transformation matrix to map between a limited set of test data obtained only from the implant and exposed regions of bone and the full model. The transformation matrix is used to predict full field results on the implant and bone. Both static and dynamic effects are considered during the modeling process.

Initial development of this methodology has involved simple analytical models. Ongoing efforts to further develop and validate this methodology include using models of increasing complexity and experimental studies.

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