Femoral Component Installation Monitoring

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1. Abstract

With emerging minimally invasive surgical techniques in total hip arthroplasty, there has been anecdotal evidence of an increase in fractures associated with the insertion of the prosthesis into the femur. The diminished visibility associated with minimally invasive surgical techniques necessitates a greater emphasis on the surgeon's tactile and auditory senses. These senses are used to ascertain the femoral component position of maximum stability and interference fit, as well as to prevent further component impaction and subsequent fracture of the femur. The work described herein attempts to identify a means to supplement the surgeon's tactile and auditory senses by using damage identification techniques normally used in civil and mechanical structures to monitor the insertion process of the prosthesis. It is hypothesized that vibration characteristics of the impact process may be used intra-operatively to determine at what position the femoral component has reached appropriate interference fit and stability in the femur. Such information may be used to prevent further impaction of the femoral component past a threshold that could result in a periprosthetic fracture. Two types of measurements will be taken: 1) A triaxial piezoelectric accelerometer and impact hammer will be used to monitor the impact process and the acceleration time histories will be analyzed, and 2) A PZT patch will be attached to the femoral component and impedance measurement taken. It is the goal of this study to determine features that can indicate when the implant is fully seated in the bone.

2. Project Outline – (about 1 page long)

2.1 Goal - What the project should accomplish.

- Investigate the femoral component installation.
- Investigate signal processing techniques that may be applicable to this problem.

2.2 Motivation – Why the project is important and how it fits into the "big picture" of real world structural dynamics.

- Over 172,000 total hip replacement (total hip arthroplasty) operations are performed each year.
- Discussion and dialogue with experienced joint replacement surgeons revealed that they typically rely on tactile sense and the change in pitch the hammer emits when contacting the impactor to determine when the implant is fully seated. With the increase of minimally invasive surgery they are losing these tactile and auditory cues.

2.3. Procedure – Steps needed to complete project.

- Literature review
- Perform modal test to characterize implant and bone/implant system.
- Attach PZT material to insert.
- Develop a test plan (What data is to be taken? How the sawbones will be supported? How will the distance the implant is inserted be measured? Etc.)
- Perform the tests on the 10 sawbones.
- Analyze the data.

- Write the report.
- Create the oral presentation.

3. Background Literature – Pertinent references students should become familiar with before and during the project. Students certainly don't have to read all of these, but the references below might give some insight into the problem.

Giardini, S., P.J. Cornwell, R.M. Meneghini, "Monitoring Femoral Component Installation using Vibration Testing," Biomedical Sciences Instrumentation, Volume 41, p. 13-18.

American Association of Orthopaedic Surgeons. (2004, Dec 22). Available: http://orthoinfo.aaos.org/booklet/thr_report.cfm?thread_id=2&topcategory=Hip

M. Jasty, R.M. Henshaw, D.O. O'Connor, W.H. Harris, "High Assembly Strains and Femoral Fractures Produced During Insertion of Uncemented Femoral Components. A cadaver study," *Journal of Arthroplasty*, pp 479-487, Oct. 1993.

X.M. Zhou, P.S. Walker, D.D. Robertson, "Effect of Press-fit Femoral Stems on Strains in the Femur: A Photoelastic Coating Study," *The Journal of Arthroplasty*, pp 71-82, Mar. 1990.

A. Aamodt, J. Lund-Larsen, J. Eine, E. Andersen, "Changes in Proximal Femoral Strain After Insertion of Uncemented Standard and Customized Femoral Stems," *The Journal of Bone and Joint Surgery (Br)*, pp 921-929, Aug. 2001.

J.J. Elias, M. Nagao, Y.H. Chu, J.J. Carbone, D.W. Lennox, E.Y.S. Chao, "Medial Cortex Strain Distribution During Noncemented Total Hip Arthroplasty," *Clinical Orthopaedics and Related Research* pp 250-258, Jan. 2000.

4. Week by Week Plan (tentative)

Week 1: (a) Literature review on total hip arthroplasty and signal processing techniques that might be appropriate
(b) Become familiar with sawbones, data acquisition system, shaker, PZT patches, etc.
(c) Formulate a test plan

Week 2: (a) Attach PZT material to hip implant.
(b) Perform modal test to characterize implant and bone/implant system.
(c) Design and build test fixture if necessary.

Week 3: Carry out tests

Week 4/5/6: Analyze Data.

Week 7/8: Report / Technical Paper writing / drafting presentation material, actual presentation.

5. **Real World Design Issues as a Project Consideration**.
   - What is would be necessary to do this in an operating room?

6. **Equipment Requirements.**
   - PZT patch
   - Sawbones and implant
   - Shaker / Amp + force transducer + one lightweight triaxial accelerometer
   - Data acquisition
   - Spectrum Analyzer or equivalent.
   - Impulse hammer (if first frequency found using a tap test).

7. **Software Requirements.**
   - ABAQUS.
   - MEScope (possibly)
   - Matlab