

# FATIGUE INDUCED DAMAGE IN CEMENTED TOTAL HIP ARTHROPLASTY CAN BE INVESTIGATED BY ACOUSTIC EMISSION

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## INTRODUCTION

Cemented total hip arthroplasty (THA) has been reported with a failure rate from 3% to 16% after 10 years of surgery [1]. Numerous clinical and biomechanical studies have been done to identify its failure mechanism [2]. It is well accepted that fatigue induced damage accumulating in the cement mantle and along the cement-bone or cement-stem interfaces is a primary mechanism.

However, little is known about the cement damage progression and related causes, due to the lack of continuous information on damage location and severity.

Recent research indicated that Acoustic Emission (AE) is a noninvasive evaluation tool that can monitor the location, growth trend and severity of fatigue damage in real time [3]. In this work, we further used AE technique to test a series of cemented THA models to explore their fatigue process. We hypothesized that: 1) AE signals could be used to study damage sites and severity; 2) cement defects, when occur in THA, would be a major cause of fatigue damage; 3) fatigue damage would be directional dependent, meaning that the damage level is different along the femoral axis.

## METHODS

Eighteen cemented THA models were prepared using Spectron hip stems (Smith Nephew Inc., Memphis, TN), 2<sup>nd</sup> generation composite femora (Pacific Research Lab., Vashon, WA) and Versabond cement (Smith Nephew, Inc., Memphis, TN). Radiographs were taken to examine cement defects. The

THA models were hinge-hinge constrained onto a servohydraulic testing machine (Fig.1) and subjected to a sinusoidal compressive load of 267/2670 N at 2 Hz for over 24 hours. Eight piezoelectric sensors (Physical Acoustics Corp., Princeton Junction, NJ) were glued onto the THA surface to monitor AE microcrack activities.



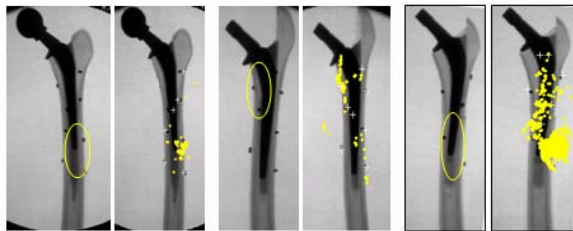
**Fig. 1:** Setup of the fatigue test.

The locations of fatigue induced AE microcracks were computed using a customized program 3DMem [3]. Based on the number of microcracks in the fatigue process, THA models were divided into two groups: Group 1 (G1) models would have significant AE microcracks (>10,000), while Group 2 (G2) models would have few microcracks. In G1 models, possible damage causes were identified according to the microcrack locations. For those without obvious causes, microcrack locations were presented in terms of proximal third, middle third, and distal third along the femoral axis. All models were transversely sectioned after fatigue tests, in 20 mm intervals from the collar to the distal tip. Cracks on section

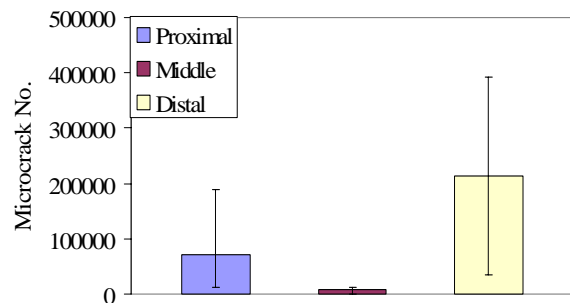
surfaces were examined with a scanning electronic microscope (SEM). Crack location and severity were compared with AE microcrack locations and numbers.

## RESULTS AND DISCUSSION

G1 had 12 THA models since a good amount of AE microcracks were detected. In these models 8 had obvious cement defects that attracted the majority of the AE microcracks (Fig.2). No obvious cause could be identified in the other 4 models, but more microcracks could be sorted into distal and proximal areas (Fig.3). In G2 models (totally 6), the number of microcracks was limited and their distribution was random. Two models had cement defects, but they did not induce any detectable microcracks.



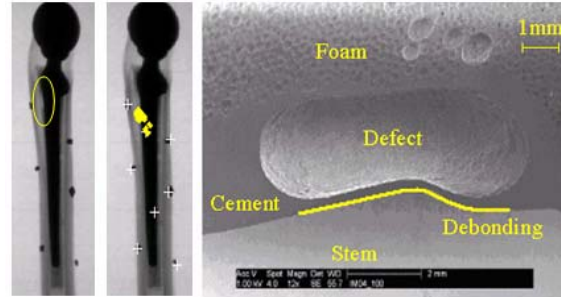
**Fig. 2** Three THA models had cement defects (marked by yellow ovals) that attracted significant AE microcracks (dots).



**Fig. 3** AE microcrack distribution along the femoral axis in the four G1 models that had no observable defects.

SEM observations were consistent with AE results. Notable damage/cracks were found

in G1 models, close to computed microcrack locations (Fig.4). No obvious cracks were observed in G2 models. This shows that the number of AE microcracks can be used as an indicator to evaluate the damage severity.



**Fig. 4** A THA model that had cement defect (left) attracted AE microcracks (middle). SEM found a debonding along the stem-cement interface next to the defect (right).

## SUMMARY/CONCLUSIONS

This study proved that AE is an efficient tool to investigate the fatigue induced damage occurred in cemented THA. Locations of computed AE microcracks were consistent with those of observed cracks with limited errors. The number of AE microcracks could be used as a parameter to evaluate the damage severity. Cement defects, although rarely seen in clinical environments, was found to be a significant damage initiator in this study. For the damaged models without obvious causes, more AE microcracks were found in the proximal and distal areas.

## REFERENCES

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