A Non-invasive Technique for Evaluation of Hip Joint Conditions Using Sound and Vibration

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Introduction: The assessment of hip joint performance for Total Hip Arthroplasty (THA) subjects is of great importance. The evaluation of THA outcome is difficult and surgeons often have to choose invasive methods for investigation. Therefore, a new non-invasive technique of digitally capturing hip joint vibration and sound emission has been developed for evaluation of hip performance and diagnosis of femoral head sliding of the acetabular component.

Materials and Methods: A non-invasive acoustic and vibration analysis technique (AVT) was developed for the measurement of transmission properties of acoustic and vibration waves in hip joints.

- Schematic diagram of AVT combined with fluoroscopic-video-capturing system and ground reaction force measurement (Figure 1). A sound sensor and a pair of tri-axial accelerometers, externally attached to the pelvic and femoral bone prominences, detect frequencies that are propagated through the hip interaction. A data acquisition system was used to amplify the signals and filter out noise generated. A fluoroscopic unit and a video camera were used to capture the in vivo weight-bearing movement of the THA as well as the leg motion during the gait activity (Figure 1). Software was developed to synchronize and record all system components (Figure 2).

Results: Four of the five subjects experienced separation. There was a distinct correlation of a high frequency sound and vibration signal occurring at the time when the femoral head slides back into the acetabular component. No sound was detected for the patient experiencing no separation. A comparison of our frequency results for the femur to previously published data proved the used method [1-3]. It was found that certain frequency ranges are excited for all implants. For some implants, certain frequencies were not present, which may be due to the different bearing surfaces having variable frequencies which are amplified while others remain insignificant. The magnitude of the vibration for subjects experiencing separation is much larger than for those without separation. This difference is more noticeable in C/C and M/M implants. Those results indicate that there is a strong possibility that separation has a significant effect on the vibration the hip is exposed to. They also indicate that C/C and M/M implants transfer more energy in the form of vibration to the surrounding tissue than C/P and M/P implants, where the energy is dissipated by the polyethylene insert. An example of the accelerations measured for the femur and the pelvis are shown in Figure 3.

Discussion: This is the first study to document a correlation of visual exploration using fluoroscopy with audible emission using a new AVT. The results from this study represent a very good correlation between the sensor data and fluoroscopic analysis, which validates the newly introduced methodology. In the future, this technique may provide information about joint conditions, and we hope it could be used to extract valuable information to enhance clinical diagnosis.