In-vivo And Ex-vivo Measurements Of Polyethylene Wear In Total Hip Arthroplasty, Comparing Measurements Using A New Ct Algorithm And A Coordinate Measuring Machine: Method And Analysis

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Disclosures:

Introduction: Total hip arthroplasty (THA) is one of the most successful surgical procedures for treatment of the arthritic hip. As THA is increasingly serving a younger and more active population, and as older THA patients are living longer, accurate and easily accessible wear measurement techniques are highly desirable. Several wear measurement techniques have been developed, ranging from simple single radiographic techniques to more advanced 3D techniques. The most accurate 3D wear monitoring method today is radiostereometric analysis (RSA). As CT scanners are widely available and used for many clinical procedures, there is a great potential for CT based measurements. In this study, numeric fitting techniques were applied to the analysis of CT volumes to identify the femoral head and acetabular cup centers and calculate the migration of the femoral component into the acetabular cup. Next we analyzed, using a Coordinate Measurement Machine (CMM), the same acetabular liners (which were explanted as part of revision surgery) as those imaged in the CT. CMM data was analyzed using a computer aided design software and was compared to the CT analysis. We also performed a micrometer analysis, comparing liner wall thickness, measuring the thickness of the polyethylene at the locations of most and least thickness. CT, CMM, and micrometer measurements were compared.

Methods: Eleven patients had available both CT scan and the polyethylene liner explant. The average age at surgery was 66 (range 42 to 89) years, and the average BMI was 27.8 (range 24.5 to 29.6). There were 5 males. The average time in-vivo for the polyethylene liner was 14.5 years (range 3.1 to 20.7), liners inner diameter (ID) nominal sizes ranged from 22 to 32mm. The mean time between CT scan and explanation was 115 days (range 214 to 13 days). To analyze CT data we used a 3D processing tool that semi-automatically identifies the center of the femoral head and acetabular cup. For the CT measurements, a large number of points (~14,000) are virtually placed on the surface of the cup. These are used to estimate, using numerical algorithms, the center of the cup. Similarly, a smaller number of points (~2000) are used to identify the center of the head. The wear 3D vector is then calculated as the difference between the centers of the head and cup. For CMM analysis the complete internal surface of each cup was measured with a line scan at 3° intervals, and 2 points per mm with the number of points per cup being ~4500 (see Figure 1). Data points were imported into a computer aided design (CAD) program, where two spheres were created to simulate the femoral head position in the cup. For each of the liners an observer aligned the two spheres such that one sphere was positioned at the femoral head designated position (pre wear position), and the second sphere was positioned in the location of maximum wear. The distance between the spheres’ centers was measured. This process was repeated five times for each cup. In addition cups were also analyzed by using a point micrometer; each of the cups was analyzed by locating the thickest and thinnest portion of the liner’s wall, and ten points were averaged around each of those locations. The difference between the thickest and thinnest portion was considered to be the amount of liner wear.

Results: We analyzed 11 THA polyethylene liners for wear, comparing in-vivo CT wear to in-vitro wear measurement. We also used a point micrometer to measure the liner polyethylene thickness comparing maximum and minimum thickness. Measurement results and differences between measurements techniques are listed in Table 2. Precision was calculated using the equation: \( \pm y = \frac{\sigma}{\sqrt{n}} \) where \( y \) was obtained from the student t-test distribution, \( \sigma \) is the standard deviation of the sample, and \( n \) is the number of observations. We used Wilcoxon rank sum test (Matlab, Mathworks Natick, MA) to test for statistical differences between the wear measurement techniques CT and CMM and CMM and micrometer, there were no differences between these measurements (p=0.623, p=0.5918 respectively). The mean difference between measuring wear using CMM and CT for all samples is 0.240±0.306 mm. We can exclude one outlier (H-12-058), since micrometer measurements indicate that the thickest point of this cup is averaging 4.83 mm and therefore wear of 5.14 mm is not possible. The updated mean wear difference between CT and CMM measurements is 0.165±0.188 mm. Comparing liner wall thickness (micrometer measurements) to CMM wear measurements, the mean difference is 0.247±0.150 mm. Table 2 summarizes the reference measurements (mean, standard deviation, Standard Error, and Precision) for the differences between CMM and CT as well as the differences between CMM and micrometer measurements.

Discussion: Measurements of polyethylene liner 3D wear in a total hip arthroplasty is currently limited to RSA studies, which
limits the type and number of patients that can be studied. In this report we compared wear measurements obtained using in-vivo CT imaging to wear measurements obtained using ex-vivo CMM readings from the same cups, additionally we measured changes in liner thickness using a micrometer. Statistical analysis indicates that there is no difference among these three methods of measuring wear. We conclude that CT imaging can be used as a clinical tool to detect early signs of polyethylene wear.

**Significance:** Our in-vivo and ex-vivo liner wear data indicate that CT technology can be used to detect early wear in the polyethylene liner of THAs. As CT scanners are available in most clinical settings, this tools can provide clinicians with the ability to follow the performance of their patients’ hip replacements.

**Acknowledgments:**

**References:**

<table>
<thead>
<tr>
<th>Measurement</th>
<th>CMM-CT (mm)</th>
<th>CMM-Micrometer (mm)</th>
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</thead>
<tbody>
<tr>
<td>Average</td>
<td>0.165</td>
<td>0.247</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>0.188</td>
<td>0.150</td>
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<tr>
<td>Standard Error</td>
<td>0.059</td>
<td>0.047</td>
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<tr>
<td>Precision</td>
<td>0.108</td>
<td>0.116</td>
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</table>

**Fig 1.**

**ORS 2014 Annual Meeting**

**Poster No: 1814**