The evaluation of manual 2D/3D registration technology and its potential to deduce prosthetic wear in patients with metal-on-metal hip resurfacing prostheses

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\textbf{Background:} Metal-on-metal hip resurfacing arthroplasty (MoMHRA) has been a popular alternative treatment for young patients with hip osteoarthritis. Despite its advantages over total hip arthroplasty, the use of MoMHRA remains controversial. Achieving the correct positioning of the prosthesis is a concern due to the higher level of difficulty and novelty of this procedure. Furthermore, it has been reported that post-operative management using 2D radiographs contains high degrees of variance leading to poor detection of prosthetic malpositioning. In order to compensate for the lack of available technology, current literature has suggested the use of blood metal ion levels as indirect predictors of prosthetic malpositioning due to the abnormal release of metal ions, particularly Chromium and Cobalt, as a result of increase wear and tear.

The purpose of this study was to determine whether 2D/3D registration technology can report prosthetic orientation in vivo and, to establish whether 3D technology can accurately deduce prosthetic wear by correlating prosthetic angles with metal ion counts.

\textbf{Material and Methods:} For this study, data from 72 patients who underwent a unilateral MoMHRA procedure in the last five years were collected. For each patient, a pre-computed tomography (CT) scan of the hip was obtained. Furthermore sagittal and coronal post-operative X-rays of the hip were evaluated. For each patient, blood metal ions were collected in serum and were converted to whole blood levels in parts per billion (ppb). In addition, four patients with post-operative CTs of the hip were obtained. To begin this study, the post-operative X-rays were used as the two-dimensional media to measure acetabular orientation. Only the acetabular component was examined in this study and acetabular orientation was defined as the function of inclination and version angles. Virtual three-dimensional models of the native, pre-operative pelvises and the acetabular implant were generated and were manually superimposed over the post-operative X-ray images according to anatomical landmarks. A manual 2D/3D registration program was specifically designed for this task. Inclination and version angles of the 2D/3D registered product were measured. For validation, the inclination and version angles of the acetabular implant were also identified in the 4 post-operative CT models, which offer the most accurate depiction of the prosthetic in vivo.

\textbf{Results:} On average, the inclination angle was measured in the radiographic evaluation with 43º (StDev 5.6 º). In the 2D/3D registered model, the average inclination angle was measured with 42.2º (StDev 6.1º). We found no significant difference between these measurements. The average version angle was measured with 16.8º (StDev 10.5º) for the radiographic evaluation and with 17.4º (StDev 6.9º) for the 2D/3D registered models. There was no significant difference in the mean values; however, we did measure a significant difference in the standard deviations (Figure 1).

For the four patients with a postoperative CT scan, we measured an average inclination angle of 44.3º (StDev 4.0º) during X-ray evaluation, 44.4º (StDev 4.7º) with the 2D/3D registered model and 44.0º (StDev 4.2º) in the postoperative CT scan. These results were not significantly different. Similarly, no
significant differences were found for the version measurements, which were on average 7.5° (StDev 6.5°) for the X-rays, 14.1° (StDev 6°) for 2D/3D registered models and 12.1° (StDev 2.6°) for the postoperative CT. When we compared the measured inclination angles (X-ray and 2D/3D-registered) with the metal ion levels we found no significant correlation between the values, as we also did not find any significant correlation between metal iron levels and version angles.

Discussion: Contrary to the study’s hypotheses and current literature, no significant difference was observed between 2D vs. 2D/3D vs. CT data, suggesting that 2D and 2D/3D measurements were similar to the results of the gold standard CT model (although 2D/3D measurements were more precise compared to 2D media). Furthermore, statistical analyses revealed no significant correlation in either 2D or 2D/3D compared to metal ion levels, although a stronger trend was demonstrated using 2D/3D measurements. These results are suggestive that 2D/3D registered measurements are equivocal to those using the conventional 2D X-ray and, manual 2D/3D registered measurements do not demonstrate greater efficacy in predicting prosthetic wear. Moreover, the data from this study also revealed insignificant correlations between the angles of acetabular orientation and metal ion release. Combined angles within and beyond the acceptable ranges for inclination (30°-50°) and version (5°-20°) angles did not produce significant trends with metal ion release.

These results lead to the paradoxical conclusion that acetabular orientation does not influence prosthetic wear. The findings of this study are inconsistent with the reports in current literature and further investigation is required.