THE USE OF IMAGE-BASED TECHNIQUES TO QUANTIFY JOINT CONTACT AREA: A COMPARATIVE STUDY BETWEEN MRI AND CT

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INTRODUCTION

Various different techniques to determine the contact area of articular joint have been described^1-3. These techniques have been shown to be useful in quantifying joint contact pressures and areas, but have only been applied in the in-vitro setting.

The application of imaging has been of increasing interest for quantifying contact mechanics and kinematics because of the potential use both in-vitro and in-vivo. There have been a few studies using Magnetic Resonance Imaging (MRI) to determine contact area at the knee^4,5. To our knowledge, there have been none using Computed Tomography (CT) to quantify joint contact area.

The purpose of this study was to evaluate the use of MRI and CT to determine contact area directly from the acquired images, and to compare with a direct measurement using a silicone casting technique employing the radiocapitellar joint of the elbow as a model of a non-congruous articulation. Our hypothesis was that MRI and CT techniques would produce values of contact area similar to a silicone casting method.

METHODS

The distal humerus and proximal radius were resected from five upper extremities, and potted in bone cement. Reprosil® (DENTSPLY International Inc. - Milford, DE), a low viscosity silicone-based dental impression material, was used to make casts of the radiocapitellar joint. After application of the casting material, the joint was loaded in compression to 100N in a materials testing machine for 10 minutes, and the solidified cast removed for analysis. Images of the casts were taken using a digital scanner and contact area was measured by tracing the line of contact (arrow). A custom-made spring loaded device was designed and fabricated. For the MRI based technique, the loading device was placed in the scanner and tracing was performed on a 3.0T system (Innovative Magnetic Resonance Imaging Systems – Winnipeg, MB) using a proton density weighted spin echo imaging technique. Imaging parameters included: field of view = 40 mm; echo time = 28 ms; in-plane image resolution = 0.16 mm. Multi-slice imaging was performed in the sagittal plane with a slice thickness of 1.5 mm. All CT scans were performed using a GE Healthcare LightSpeed Plus 4-slice PET/CT scanner (GE Healthcare Technologies – Waukesha, WI, USA). The specimen was scanned using a helical scan at 120kVp and 100mA. Other imaging parameters included: resolution = 0.70 mm; field of view = 96 mm; slice thickness = 0.16 mm. To measure the contact area from the MRI and CT images (Figure 1), reconstruction software was used (Mimics 9.0, Materialise – Ann Arbor, MI, USA). The contact area was measured directly from the images by three independent observers. The contact area was determined by measuring the length of visible contact between the capitellum and the radial head in each slice, multiplying this length by the slice thickness, and summing these values to obtain a total contact area in square millimeters.

RESULTS

The error in contact area of repeated castings was less than 2.4% of the mean average measured value. The maximum variation within the observers for CT and MRI techniques for each observer was determined to have a Coefficient of Variation (CV) of 4.5% and 6.4%, respectively. The maximum variation (CV) between the three observers for CT and MRI was 6.7% and 10.2%, respectively.

The mean contact area measurements for the casting, MRI and CT techniques were 127.9 ± 16.6 mm², 124.7 ± 2.5 mm², and 140.5 ± 19.4 mm², respectively (Figure 2). There was no significant difference between the three contact area measurement techniques (p = 0.12) and also no significant difference between CT and MRI (p = 0.10).

DISCUSSION

The aim of the study was to evaluate the use of Magnetic Resonance Imaging and Computed Tomography to determine joint contact area of a non-congruous articulation. From our results, CT seemed to consistently overestimate the contact area, and this may have been due to MRI lacked consistency when comparing to the casting technique but this was not statistically significant. The inconsistency of MRI may have been a result of image quality as the line of contact was difficult to determine in some slices.

The results of this study show that the use of MRI and CT to measure contact area is promising. Despite some limitations, the images produced values very similar to that of the experimental-based technique, which has been previously shown to be very reproducible and accurate^1. This is the first study to compare imaging techniques to experimental techniques for measuring contact area at the (radiocapitellar joint of the) elbow. We compared the most clinically-applicable imaging modalities for quantifying contact mechanics, which may eventually lead to in-vivo measurements.

In summary, this study suggests that imaging has the potential to quantify joint contact for non-congruous joints as examined herein. Automation of the system to determine the contact perimeter directly, and project that onto the articular surface will be an important contribution to the investigation of joint biomechanics.

REFERENCES


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Figure 1: Example of images from MRI (left) and CT (right) showing line of contact (arrow).

Figure 2: Contact area of the casting, MRI, and CT techniques (Error bars are +1 standard deviation, n=5).

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