ACCURACY OF OSTEOPHYTE DETECTION IN CONVENTIONAL COMPUTED TOMOGRAPHY AND MAGNETIC RESONANCE IMAGING OF JOINTS

Noor Al-Attar MSc[*1], Gabriel Venne MSc DO[2], Ronald Easteal PhD[3] and Manuela Kunz PhD[4]

[1*] Human Mobility Research Centre, Queen's University, Kingston ON, K7L 2V7, Canada, 12anaa@queensu.ca

[2, 3] Department of Biomedical and Molecular Sciences, Queen's University, Kingston ON, K7L 3N6, Canada

[4] School of Computing, Queen's University, Kingston ON, K7L 2V7, Canada

INTRODUCTION

One of the factors affecting the reliability of image-guided surgical interventions such as patient-specific guided procedures, is the accurate depiction of the registration surface in the pre-operative image modality. This requirement is critical when working with patients with osteoarthritis, a disease characterized by the breakdown of articular cartilage and the development of osteophytes (Turmezei & Poole, 2011). These abnormal osteo-cartilagenous anomalies form along joints and are highly variable in density and composition; thus, their capture using imaging modalities is difficult and unreliable (Gelse *et al*, 2003).

Various studies have hypothesized that osteophytes may be related to increased post-operative errors. Seon *et al* suggested that outliers in patient-specific guided knee procedures resulted from osteophytes (Seon *et al*, 2014). Kunz *et al* found that osteophytes not accurately identified in a pre-operative CT scan could result in instrument alignment errors up to 2.7° (Kunz *et al*, 2015).

Results from such studies demonstrate the need to examine the accuracy of osteophyte detection using conventional clinical CT and MRI scan protocols in order to define an optimal imaging protocol for the best osteophyte depiction. Thus far, no one has looked at manipulating varying imaging parameters (for both CT and MRI) to increase the accuracy of osteophyte detection.

MATERIALS AND METHODS

A vertebral (lumbar) and knee specimen were selected for the study. Each specimen was subjected to CT and MR imaging – with segmentation of the datasets – dissection, and structured 3D light scanning.

The CT protocols were aimed at testing three different parameters within a clinical range and their effect on image acquisition quality: the x-ray voltage (100, 120, and 140kVp), slice thickness (1.25, and 2.5mm), and scan type (axial, and helical).

Three different MRI imaging protocols were tested: T1-weighted (T1W), T2-weighted (T2W), and application of fat suppression. During all scans the specimens were maintained in a supine position within a 12-channel head matrix (Siemens). Slice thicknesses ranged from 1.2-2.0 mm.

After all scans were obtained, specimens were carefully dissected to remove all soft-tissue surrounding the joint to expose the bony and articular surface of the joint.

An Artec Spider (Artec Group, Luxembourg) 3D handheld structured light scanner, with a published accuracy of up to 0.1mm, was used to digitize the surface topography of the joints (Figure 1).

The 3D models were generated using Mimics (Materialise, Leuven, Belgium) using semi-automatic and manual editing functions. Experienced users carefully segmented the data to represent the anatomical surface with the highest possible accuracy (including osteophytes).

To measure the accuracy of osteophyte depiction, an RMS error (RMSE) for each model was determined, measuring the distance of the osteophyte surface compared to the light scan model.

A paired, one-tailed t-test was used to evaluate significant differences between parameters. An F-test was performed determining the population data to be normally distributed.

RESULTS

Based on inspection during the dissection, the osteophyte in the vertebral specimen was considered to be very mature (fully calcified), while the osteophyte on the tibia was immature (partially cartilaginous).

The notable results identified that 120kVp was significantly more accurate in depicting the vertebral osteophyte (RMSE= 1.063mm), and a specific combination of an axial scan at 120kVp and 1.25mm yielded the highest accuracy (RMSE= 0.982mm; Figure 2A). Of the MRI results, a T2W scan was most accurate (RMSE= 1.436mm; Figure 2B).

For the tibial osteophyte, 100kVp was more favourable (RMSE= 1.253mm) though the highest accuracy was found in an axial scan at 120kVp and 1.25mm (RMSE= 0.910mm; Figure 2C). However, similar results were found at 100kVp (RMSE= 0.927mm). A T1W scan produced the lowest error for the tibial specimen (RMSE=0.810mm; Figure 2D).

Overall, the average RMS errors for CT and MRI scanning were 1.169mm and 1.419mm, respectively. The combined CT results for all specimens indicated that a slice thickness of 1.25mm was significantly more accurate (p= 0.004; RMSE= 1.056mm) than 2.5mm. In addition, both 100kVp and 120kVp were significantly more accurate when each were compared to 140kVp (p= 0.015 and p= 0.011, respectively).

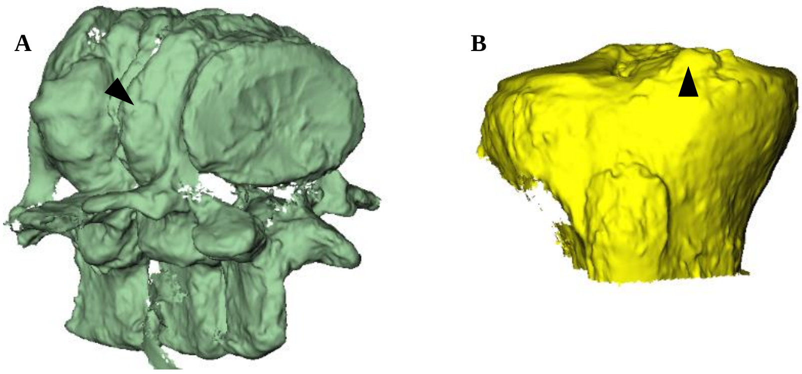

Figure 1. Light scan images of the A) vertebrae, and B) tibia. The arrowheads indicate the osteophytes under study.

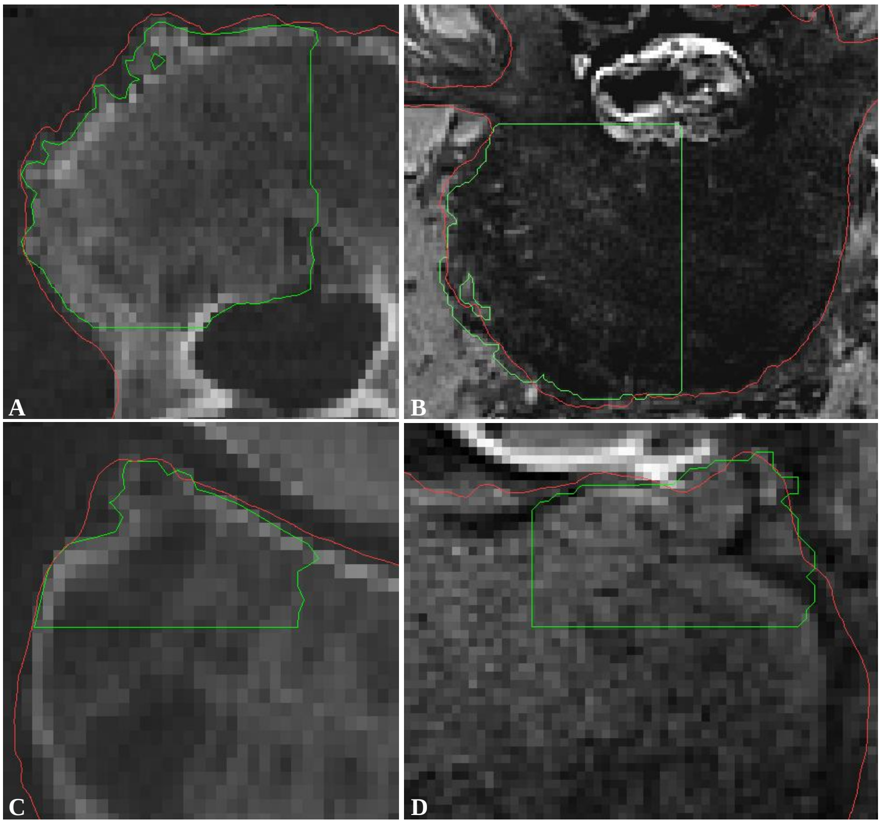

Figure 2. The CT (left) and MRI (right) scans depicting the highest accuracy of osteophyte depiction in the vertebra (top) and tibia (bottom). The contour lines of the light scan models and segmented osteophytes are indicated in red and green, respectively.

DISCUSSION

Our results demonstrate a difference in osteophyte depiction between imaging modalities, and between varying parameters within each modality.

A CT voltage lower than 140kVp was more favourable for an accurate depiction of the osteophyte. However, the more calcified osteophyte in the vertebra was better depicted with CT scanning at the higher 120 voltage, while the developing osteophyte that consisted of cartilaginous components was better depicted using a lower voltage. These varying results support the previous suggestions that osteophytes are not accurately identified with clinical CT imaging (Kunz *et al*, 2015). They also suggest that accurate depiction of an osteophyte is likely dependent on the degree of calcification of the osteophyte. With a premature osteophyte, the tissue's lower density allows for excellent contrast with surrounding tissue in an MRI relative to a CT, which is likely to explain the high degree of accuracy in the T1W scan of the tibia.

The consistency of a smaller slice thickness providing a more accurate osteophyte depiction across specimens supports the literature in that a smaller slice thickness yields a higher resolution (Seeram, 2009).

These preliminary findings suggest that the imaging required for accurate osteophyte depiction relies on several factors, including the size, age, and composition of the osteophyte. Consequently, the stage of osteoarthritis in patients can be used as a potential determinant for the appropriate imaging protocol applied.

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DISCLOSURES

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