EVALUATION OF NEW SOFTWARE FOR CARTILAGE THICKNESS ESTIMATION IN KNEE MR IMAGES WITH SEVERE METALLIC ARTEFACT

Ryan Nazareth[1], Peter Cashman[2], Pauline Parlier[2], Anastasia Papadaki[1], Lesley Honeyfield[1], Keshthra Satchithananda[1], Donald McRobbie[1] and Fiona Watt[3]
[1]Imperial College Healthcare NHS Trust, United Kingdom, [2]Imperial College London, United Kingdom, [3]Kennedy Institute of Rheumatology, United Kingdom

Background

- Monitoring cartilage thickness is desirable in those with knee injuries who are at high risk of early osteoarthritis
- The presence of MR artefact from metal implants in the bone can greatly complicate reliable segmentation of cartilage from the images
- Previous published works on automated methods for cartilage thickness estimation have described validation studies using images of near-perfect quality
- Our group has validated the reliability and accuracy of semi-automated in-house software program KneeSeg2 [1] in measuring cartilage thickness from images affected by severe metal artefact

Method

- A phantom imitating knee geometry was designed as two Perspex cylinders filled with bone and cartilage mimicking gels and perspex rods positioned on the outer cylinder surface, providing angular landmarks every 30° for measuring cartilage thickness (Figure 1A)
- A titanium surgical screw was added to generate metal artefact in the images (Figure 1B)
- Images of the phantom and volunteer (Figure 1D) were acquired on a Siemens 3T Magnetom Verio MR scanner with an 8 channel knee coil using a Double Echo Steady State sequence [2]
- Semi- automated and manual cartilage thickness measurements were carried out offline using KneeSeg2 and Siemens Magnetom Verio Syngo MR B17 software respectively

Segmentation Steps

- Median filtering is applied to remove noise
- Convolving with a Sobel kernel produces a gradient magnitude image which is then thresholded to produce a binary image of the bone, cartilage and artefact edges
- Metal artefact within the bone is removed using the bone artefact mask (BAM), an adaptive contour manually preset by the user, which surrounds and nulls the metal artefact but does not impinge on the bone-cartilage boundary
- Conventional closing and dilation of the binary bone region produces a shell which is used as a mask to pre-segment the cartilage from the original image (Figures 1C and E)
- The final segmented cartilage thickness is computed by searching outwards from a search origin positioned in the centre of the bone until the inner cartilage boundary is reached, and then proceeding in a direction normal to the bone-cartilage interface until the outer cartilage boundary is reached
- This procedure is repeated automatically for all slices in the volume and a cartilage thickness map is generated using cylindrical projection. The BAM shape adapts itself from each slice to the next.

A) B) C) D) E)

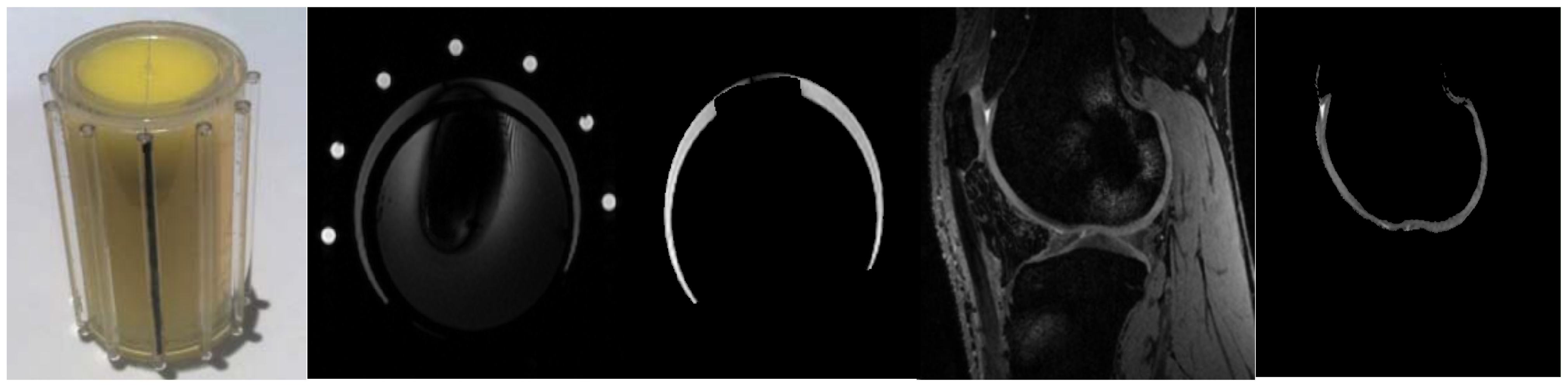

Figure 1: A) Cylindrical phantom simulating knee geometry. Inner cylinder is eccentric to provide a smooth variation of cartilage thickness with angle. B) Image of the phantom showing metal artefact within the bone and impinging on the cartilage; also the seven angular markers provided for precise location of the cartilage measurements. C) Segmented phantom cartilage obtained using the KneeSeg2 software. D) Sagittal image of patient knee with severe metal artefact within the trabecular femoral bone. E) Cartilage segmentation using KneeSeg2 after applying the special bone artefact mask.

Results

- Bland-Altman analysis [3] was used to quantify the agreement between automated and manual measurements at the same locations, for both phantom and clinical data sets
- At our centre, the clinically acceptable thresholds for the bias and limits of agreement (LOA) with such measurements are defined as 0.2mm and 1mm respectively
- In both the phantom and clinical data sets (Figures 2A and B), there was a clinically acceptable level of agreement between the manual and automated measurements, except for those slices in the phantom images where the metal artefact impinged onto the cartilage (Figures 1B and C). These are represented by the yellow points in Figure 2A.
- Provided the operators preset the BAM consistently, KneeSeg2 analysis gave identical results when repeated over time within and between operators

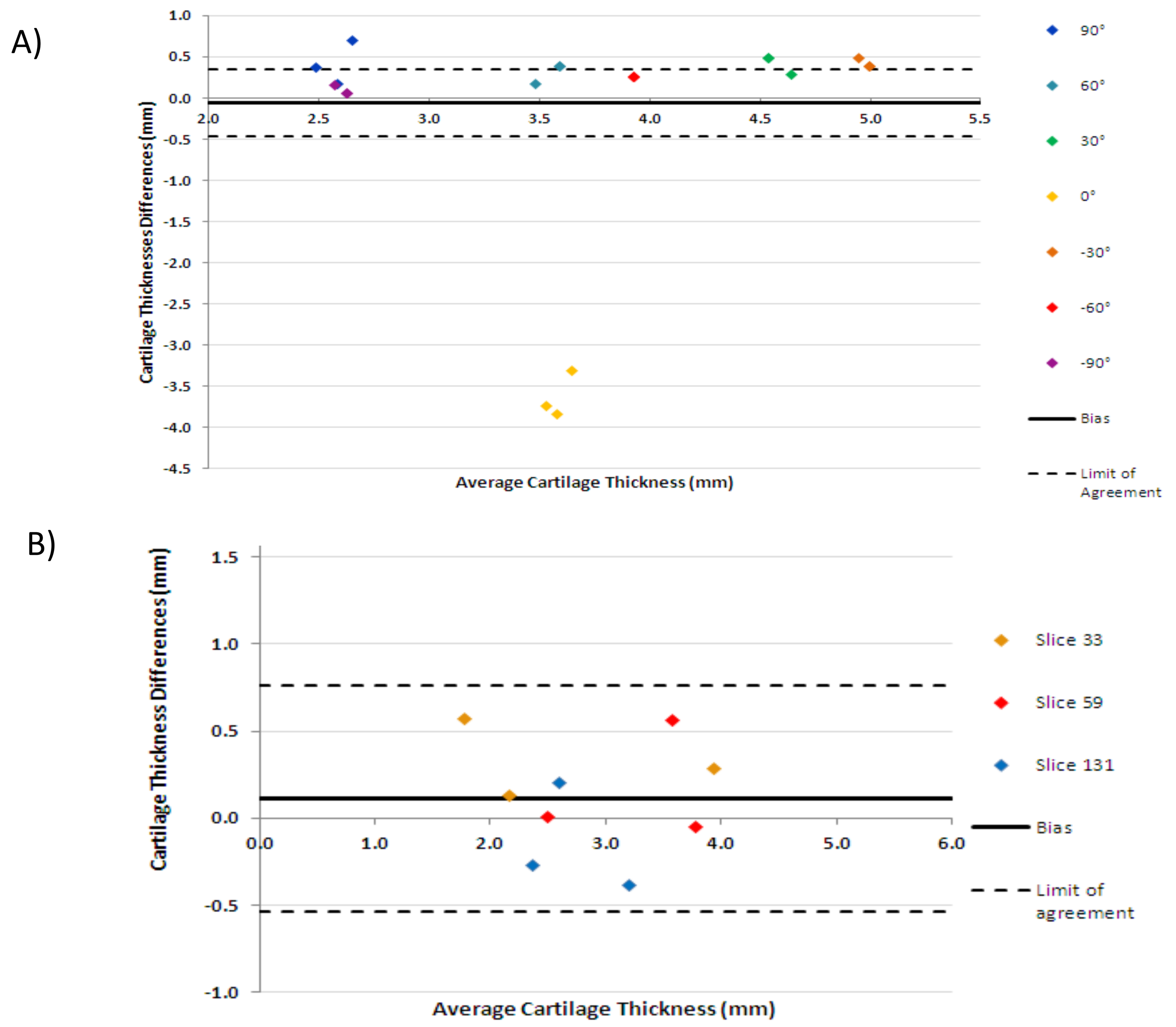

Figure 2: A) Bland-Altman comparison of manual versus automated cartilage thickness for the phantom. Each set of coloured points corresponds to the same angular measurement on three different slices. The yellow points correspond to the location where the intrusive artefact is dominant. B) Bland-Altman comparison of manual versus automated cartilage thickness for the clinical data set. Each set of coloured points corresponds to three different angular measurements on the specified slices. All points were found to lie within the clinically acceptable bias and LOA thresholds.

Conclusions

- The KneeSeg2 program successfully segmented the cartilage boundaries on clinical images containing metallic artefact, provided the artefact was all contained within the bone
- In comparison with the manual measurements, KneeSeg2 offered the same level of accuracy and precision but a substantial reduction in time, robustness to changes in the display contrast and brightness, good inter-observer agreement and repeatability

References

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[3] J.Bland et al. Lancet 1986;1(8476):307-310