Validation of Cartilage Thickness Calculations Using Indentation Analysis

M. F. Koff1, L. Chong2, P. Virtue3, D. Chen4, T. Wright4, and H. Potter5

1Department of Radiology and Imaging, Hospital for Special Surgery, New York, NY, United States; 2Department of Diagnostic Radiology, Changi General Hospital, Singapore; 3GE Healthcare, Waukesha, WI, United States; 4Department of Biomechanics, Hospital for Special Surgery, New York, NY, United States

Introduction. Osteoarthritis (OA) is a degenerative disease of articular cartilage. Radiography is commonly used to determine the grade of OA within a joint [1], but only provides an indirect measure of cartilage thickness. Magnetic resonance imaging (MRI) is a non-invasive method for quantifying cartilage distribution within a joint [2]. Three dimensional (3D) spoiled gradient-recalled echo (SPGR) images are commonly used to calculate cartilage thickness and volume [3,4]; however, a limited number of cartilage thickness validation studies have been performed (e.g. [5-8]). While these studies have acquired histological [6-8]; computed tomography arthrography [5] or ultrasound [9] data for cartilage thickness validation, these methods have relied on point-to-point measurements and 3D cartilage thickness calculations allowed for out of plane curvature of the articular surface, which may have an effect when attempting to validate cartilage thickness measurements [8]. In addition, the mean difference of the current measurement is 40% smaller than another validation study [7] and only 2.9% of the current thickness differences were greater than 0.5mm [6]. A strength of the current study was the ability to align the biomechanical and imaging datasets. Furthermore, the 3D indentation measurements are 0.218 mm (mean ± st.dev.), with the MR measurements being slightly thinner than the corresponding indentation measurements (Fig. 3). The repeatability of the measurements was 0.43 mm.

Results. A total of 69 paired MRI-indentation thickness data points have been analyzed from 4 bovine condyles. The results of the regression analysis are shown in Figure 2. The Pearson correlation coefficient (r) was 0.9. The Bland-Altman analysis found differences of 0.047±0.218 mm (mean ± st.dev.), with the MR measurements being slightly thinner than the corresponding indentation measurements (Fig. 3). The repeatability of the measurements was 0.43 mm.

Discussion. The present study used a custom designed L-shaped phantom to register the indirect MRI cartilage thickness calculations with direct indentation cartilage thickness measurements. The one-to-one analysis of the data is a benefit over previous studies which have validated MRI cartilage thickness measurements by using interpolated or regional thickness measurements. The correlation found in this study is similar to a previous report of MR and direct cartilage thickness measurements [8]. In addition, the mean difference of the current measurements is 40% smaller than another validation study [7] and only 2.9% of the current thickness differences were greater than 0.5mm [6]. A strength of the current study was the ability to align the biomechanical and imaging datasets. Furthermore, the 3D indentation measurements and 3D cartilage thickness calculations allowed for out of plane curvature of the articular surface, which may have an effect when attempting to validate cartilage thickness measurements [11]. This study will aid in validating a tool for clinical evaluation of in-vivo cartilage thickness.

Acknowledgements. Xiaonan Wang for assistance with the indentation testing.