Automatic ICRS Scoring of Cartilage Lesions using Arthroscopic OCT Images

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Introduction: Articular cartilage injury is a common cause of chronic disability in both humans and animals. Current treatment strategies offer several possibilities and in order to select the optimal repair procedure, accurate determination of size and severity of a lesion is important [1,2]. Recently, an equine *ex vivo* study showed that arthroscopic optical coherence tomography (OCT) provides high resolution optical images of the cartilage layer [3]. Furthermore, in that study morphological characteristics of cartilage including depth of lesions could be more accurately determined than with conventional arthroscopy. Although the inter- and intra-investigator agreement by means of OCT is better than with conventional arthroscopy [43.9% versus 31.7% and 68.9% versus 56.7%, respectively] [4], reproducibility of OCT based articular cartilage grading needs improvement. Especially, avoiding the subjectivity introduced by assessment by individual surgeons would be a great step forward. In this study we aim at introducing a first version of software capable for automatic and reproducible ICRS-scoring of cartilage lesions.

Methods: For this study, metacarpophalangeal joints of eighteen equine cadaver front limbs were used. The joints were opened and for each joint five sites of interest (SOIs), supplemented with other locations where cartilage defects were encountered by *ex vivo* arthroscopic OCT imaging in an earlier study [3], were sawed into osteochondral blocks. Samples were placed in phosphate buffered saline (PBS) and scanned with a clinical intravascular OCT instrument (ILUMIEN PCl Optimization System, St. Jude Medical; wavelength 1305 ± 55 nm, axial resolution <20 µm, slice thickness 100 µm). A total amount of 101 OCT images was created and used for automatic ICRS scoring. Automatic scoring software was created in Matlab (version R2010a, MathWorks company, Massachusetts, USA). The entire automatic scoring process is summarized in figure 1. During preliminary image processing the known OCT catheter diameter (d = 0.9 mm) is obtained in pixels which is subsequently used for calibration. The image, the contrast of which is increased to enhance the cartilage-bone interface, is then rotated so that the articular surface is oriented horizontally. The manually selected area of interest (2 x 3.5 mm^2) is extracted from the image and contrast is enhanced again. Subsequently, cartilage thickness and relative lesion depth are determined. Next, the roughness of articular surface is quantified as optical roughness index (ORI) [5]. The ICRS score of the cartilage is determined along the protocol shown in figure 2. A lesion that extends through the cartilage-bone interface, is graded as ICRS 4, if the lesion depth exceeds 50% of the cartilage thickness it is graded as ICRS 3. A lesion between 10% and 50% of the cartilage thickness is graded as ICRS 2 and if the ORI is greater than 3.5 µm, ICRS grade 1 is granted. If none of the above criteria is applicable, the cartilage layer is graded as ICRS 0. Automatic scoring was repeated three times, with separated manual positioning of the area of interest, and reproducibility of the software was determined by calculating the intra-investigator agreement percentage.

Results: The software was capable of calculating an ICRS grade for all images included in this study. The intra-investigator agreement was 79.2%.

Discussion: The present preliminary data indicate that automatic ICRS-scoring of arthroscopic OCT images achieved a higher reproducibility compared to manual scoring in an earlier study [79.2% versus 68.9%] [4]. Variation in automatic scoring was mainly caused by variation in manual positioning of the analysis window, lack of image contrast at the cartilage-bone interface and shadows related to debris in the PBS. This indicates the potential for a further increase in reproducibility when using images with better quality. It must be noted that the present results are very preliminary and produced using the very first version of the software. Thus, with further development of the software higher reproducibility of scoring is expected. As a next step the present results of automatic scoring will be compared to manual scoring of the same set of images by several observers and accuracy of automatic scoring will be investigated by comparison with histological and biomechanical data.

Significance: Automated ICRS-scoring of cartilage lesions could improve reproducibility and reliability of diagnosis. This could help to chose the best treatment option and to make prognoses more reliable.

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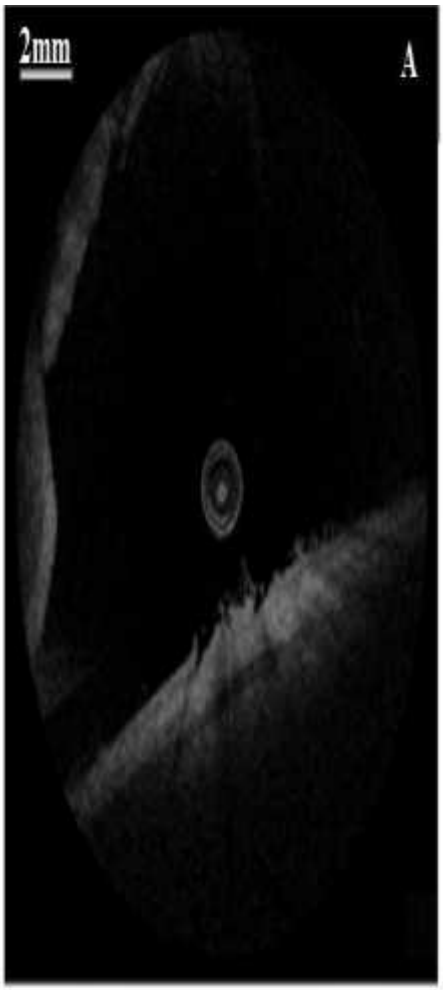
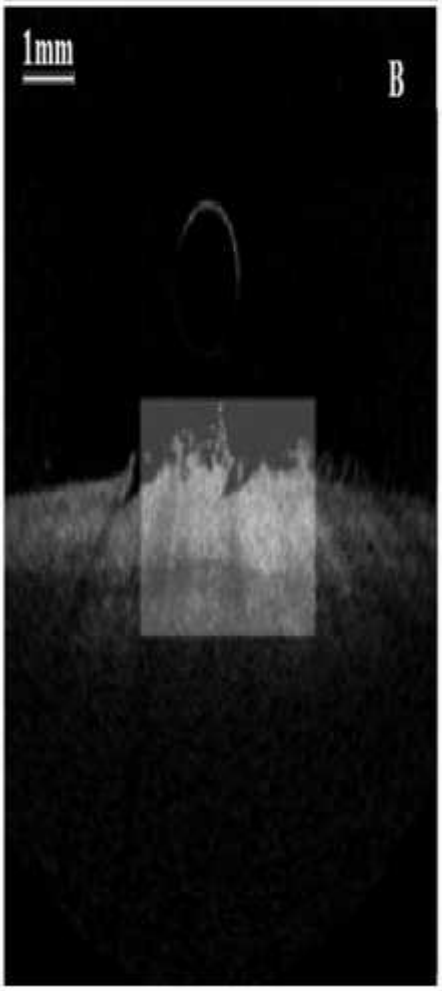
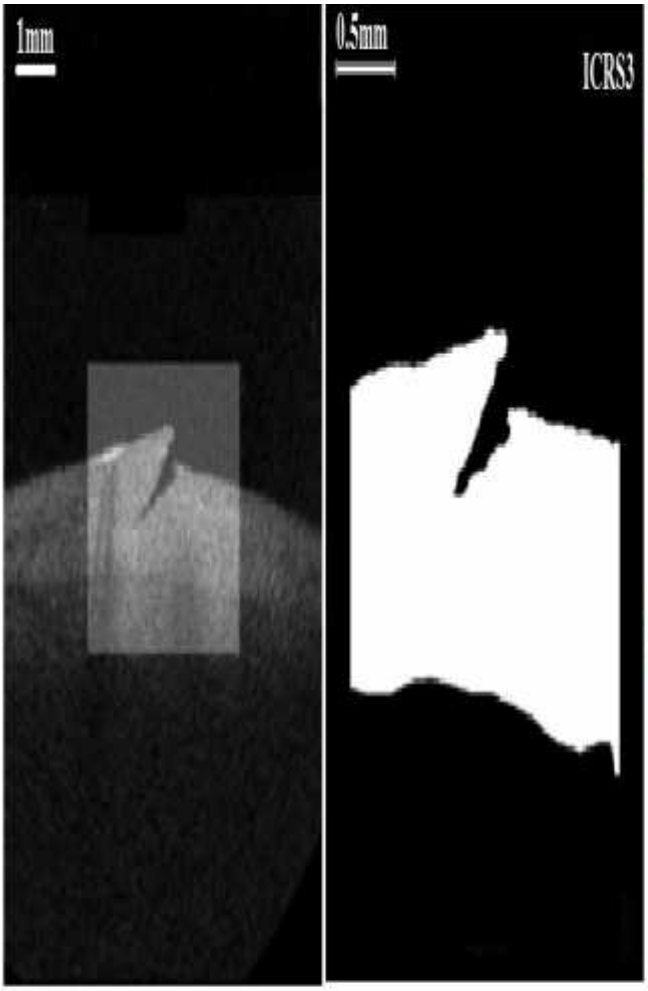


Image dimensions are calibrated based on known diameter (d = 0.9 mm) of the OCT catheter (A)

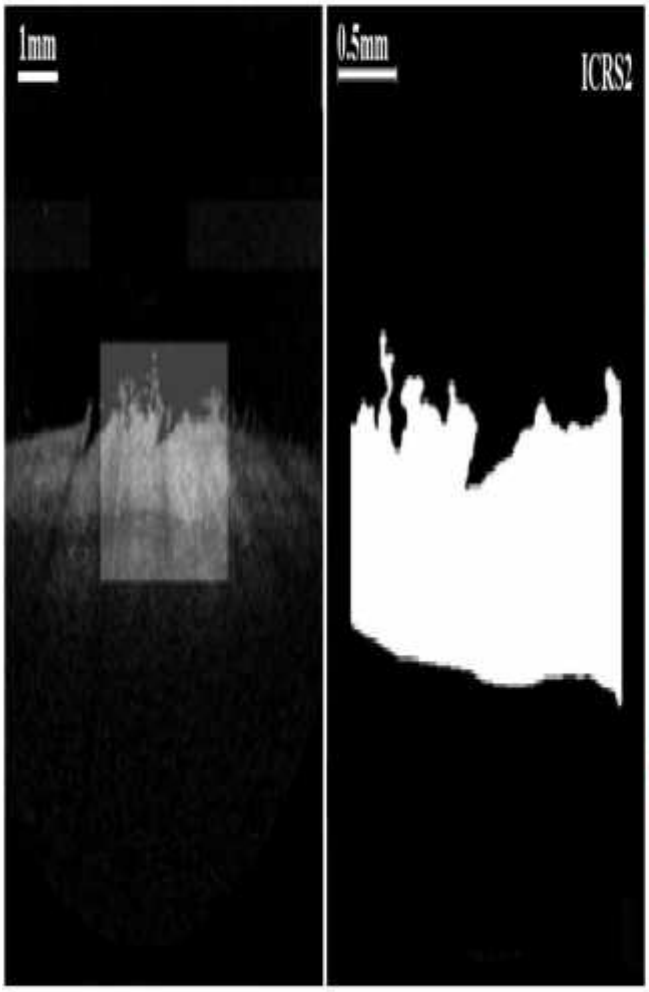


The image is rotated so that the articular surface is oriented horizontally. Image contrast is enhanced to enable segmentation of cartilage. Area of interest is manually selected (B).

The area of interest is extracted for quantitative analysis (C). Cartilage thickness, relative lesion



Lesion depth > 50% of cartilage thickness → ICRS 3



50% > lesion depth > 10% of cartilage thickness → ICRS 2

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