3D ULTRASOUND BIOMICROSCOPY FOR ASSESSMENT OF CARTILAGE REPAIR TISSUE: VOLUMETRIC CHARACTERISATION AND CORRELATION TO ESTABLISHED CLASSIFICATION SYSTEMS

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Abstract

Objective and sensitive assessment of cartilage repair outcomes lacks suitable methods. This study investigated the feasibility of 3D ultrasound biomicroscopy (UBM) to quantify cartilage repair outcomes volumetrically and their correlation with established classification systems. 32 sheep underwent bilateral treatment of a focal cartilage defect. One or two years post-operatively the repair outcomes were assessed and scored macroscopically (Outerbridge, ICRS-CRA), by magnetic resonance imaging (MRI, MOCART), and histopathology (O'Driscoll, ICRS-I and ICRS-II). The UBM data were acquired after MRI and used to reconstruct the shape of the initial cartilage layer, enabling the estimation of the initial cartilage thickness and defect volume as well as volumetric parameters for defect filling, repair tissue, bone loss and bone overgrowth. The quantification of the repair outcomes revealed high variations in the initial thickness of the cartilage layer, indicating the need for cartilage thickness estimation before creating a defect. Furthermore, highly significant correlations were found for the defect filling estimated from UBM to the established classification systems. 3D visualisation of the repair regions showed highly variable morphology within single samples. This raises the question as to whether macroscopic, MRI and histopathological scoring provide sufficient reliability. The biases of the individual methods will be discussed within this context. UBM was shown to be a feasible tool to evaluate cartilage repair outcomes, whereby the most important objective parameter is the defect filling. Translation of UBM into arthroscopic or transcutaneous ultrasound examinations would allow non-destructive and objective follow-up of individual patients and better comparison between the results of clinical trials.

Keywords: Cartilage – repair/regeneration, ultrasound biomicroscopy, Outerbridge, ICRS-CRA, MOCART, O'Driscoll, ICRS-I, ICRS-II.

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Introduction

In recent years, the spectrum of cartilage repair techniques has increased remarkably. Macroscopic evaluation, magnetic resonance imaging (MRI) and histological preparation are usually used to characterise the cartilage repair outcomes. For each method several scoring systems were developed, which have been partially validated and recommended by the International Cartilage Repair Society (ICRS) (Buschmann and Saris, 2011).

The depth of native articular cartilage lesions can be scored macroscopically and intraoperatively by the surgeon according to the Outerbridge score (Outerbridge, 1961) or by the newer and more specific ICRS Grade. For cartilage repair outcomes the ICRS recommends the Cartilage Repair Assessment (CRA) scoring system in the ICRS Cartilage Injury Evaluation Package with three distinct categories: "degree of defect repair", "integration to border zone", and "macroscopic appearance". However, intraoperative scoring according to Outerbridge, ICRS, and ICRS-CRA scales involves a large subjective component resulting in high inter-observer variability (Bonasia *et al*., 2015; Cameron *et al*., 2003). In addition, macroscopic judgement of the cartilage repair outcome does not allow for assessment of the cartilage thickness unless the bone is exposed. Furthermore, the repair tissue can mask problems in the sub-superficial repair region; an apparently well-filled lesion may hide undesirable malformation of the subchondral bone plate. However, in recent years, the awareness of the subchondral bone as one important aspect of cartilage repair has increased (Gomoll *et al*., 2010).

MR imaging provides visualisation of the whole joint with high soft tissue contrast and allows for assessment of the cartilage layer, the underlying bone as well as surrounding soft tissue. It can also be used for non-invasive follow-up of cartilage repair. According to the recommendations of the ICRS, assessment of the cartilage layer and the underlying bone compartment should be performed according to the nine categories of the 2D Magnetic Resonance Observation of Cartilage Repair Tissue (MOCART) scheme (Ebert *et al*., 2014; Marlovits *et al*., 2006). As already shown, some MRI-based classification systems and single items of the MOCART score correlate with clinical outcomes after cartilage repair (Blackman *et al*., 2013; Windt *et al.,* 2013a). However, the correlation strength also changes depending on the repair approach. At this time, "no current MRI classification system has been shown to correlate with clinical outcomes