FEASIBILITY OF ARTHROSCOPIC INDENTATION MEASUREMENTS FOR IN VIVO EVALUATION OF HUMAN KNEE JOINT ARTICULAR CARTILAGE

INTRODUCTION: Several laboratory studies [1,2] have suggested that mechanical indentation measurements can offer diagnostic information on cartilage integrity not reachable during qualitative arthroscopy. However, arthroscopic in vivo measurement of cartilage stiffness presents several challenges not present in laboratory testing. In this study, we tested in vivo feasibility of two models of commercial indentation instrument [3].

MATERIALS AND METHODS: First, elastomer samples with varying stiffness and thickness were tested in a laboratory to compare indentation characteristics of two models of a commercial, clinically used indentation instrument (Artscan (AS) 1000 and 200, Artscan Ltd, Helsinki, Finland). As both models are still in use there is a need to characterize possible differences.

AS 1000, but not AS 200, has been extensively tested in laboratory. Therefore, prior to in vivo testing, AS 200 was tested in situ with bovine cartilage. Subsequently, the arthroscopic indentation measurements were conducted independently by two surgeons in Finland (AS 1000, n = 20) and USA (AS 200, n = 18). Measurement sites were located at the center of lateral and medial femoral condyles (LFC, FMc) and tibial plateaus (LTP, MTP). Mean age of the patients was 30.7±10.1 years, BMI ranged 18.8-38.8 (mean 26.4). Cartilage surfaces of the knee were evaluated visually by using the guidelines of ICRS [4]. While the difference between the cartilage visual grades 0 (normal) and 1 (superficial lesions, minor superficial fissures and cracks, softening) depends subjectively on the surgeon’s decision, all patients with ICRS grade 0 and 1 were accepted for the study.

For the in vivo indentation measurements, a portal was made on a side of the patellar ligament and the measurement rod of the indentation instrument was inserted into the knee joint (Fig. 1). The arthroscopic measurements were systematically conducted twice at both sites of the knee to enable analysis of measurement reproducibility (root mean square coefficient of variation (CV)). Kruskall-Wallis post hoc test was used to compare the differences in indentation stiffness between the measurement sites. The study was approved by the local authorities and patients underwent informed consent at both sites.

RESULTS: Laboratory measurements indicated that indentation stiffness values were 13% higher for AS 1000 as compared to AS 200. The linear fit equation \( y = 0.632x + 0.008 \) \( \left( r^2 = 0.977, p = 0.01 \right) \) was calculated and used for matching measurement values of AS 1000 with those of AS200. Indenter forces of bovine knee articular cartilage, as measured in situ with the Artscan 200, correlated linearly with the reference dynamic moduli (Fig. 2b). In both hospitals the indentation stiffness values of the visually normal cartilage were similar and showed topographical variations with significantly \( (p<0.01) \) higher values at the FMC and LFC, as compared to MTP and LTP (3.17±0.76 N, 3.46±0.91 N, 1.17±0.49 N, 1.43±0.53 N, respectively). Mean reproducibility (CV) of the measurements was 9.8% (range 6.2-12.1%) between the measurement sites, Fig. 3 in the case of an experienced operator.

CONCLUSIONS: Stiffness of both human and bovine cartilage was lower in the tibial plateaus, as compared to that of femoral condyles. This is in agreement with earlier studies [5]. The reproducibility of the arthroscopic indentation measurements was not significantly dependent on the measurement site in the knee. It was seen that the arthroscopic indentation measurements of an experienced operator were reproducible with a mean CV=9.8%, suggesting that a change of ~28% [6] in stiffness is needed to reveal a true change when monitoring an individual patient. As even higher changes in cartilage dynamic modulus take place during cartilage degeneration [7], or repair process, the instrument realistically enables diagnostics and follow-up.

The laboratory measurements have revealed no differences in the reproducibilities of AS 1000 and 200. However, reproducibility of the clinical indentation measurements was found to depend on the experience of the operator to use the instrument, being significantly lower for an unexperienced operator (typical CV~30%). This emphasizes the need for comprehensive pre-training of the operator. Possibly, the local, spot-like in vivo measurements may be impaired by the difficulties in reproducible localization of the indentations.


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