CARTILAGE MECHANICS: LOW-ENERGY WATER JET ALLOWS TO DIFFERENTIATE CARTILAGE QUALITY

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INTRODUCTION: In order to assess the efficacy of articular cartilage repair procedures for trauma, osteoarthritis or other diseases, quantitative information about cartilage quality can be obtained from compressive stiffness measurements. Small handheld devices have been developed to determine arthroscopically cartilage mechanical properties by indentation [1]. Cartilage appears to be highly sensitive to mechanical deformation. Therefore a device, which determines the stiffness of soft materials without compromising the healing tissue, will have advantages compared to common indentation instruments. The aim of the study was to validate the measuring of different cartilage qualities in vitro using a new low-energy water jet system.

METHODS: A method was developed to measure mechanical stiffness of soft biological materials arthroscopically (e.g. joint cartilage) without direct contact between the tip of the measurement device and the measured object. Deformation is produced by a defined flow of liquid (NaCl) and measured optically (mean error < 5 µm). The technical solution is applicable to measure mechanical stiffness of native, degenerated and regenerated joint cartilage and other soft biological materials. Eight non-paired knees (sheep, two years) were retrieved and stored at -20°C until testing. The medial femoral condyle and the lateral tibia plateau were potted in PMMA for mechanical testing (native group). The lateral femoral condyle and medial tibia plateau were placed in 0.1%-trypsin solution (Merck KG, Germany) at 37°C for 48h to simulate cartilage degeneration [2]. After Trypsin treatment, the degenerated group was potted. During mechanical testing, the cartilage samples were rinsed with 0.9%-NaCl-solution. Cartilage stiffness was non-destructively determined using the new water jet system during indentation testing in a materials testing device (Zwick 1455, Germany) according to Mow et al. [3]. For each sample, 6 consecutive measurements were performed.

RESULTS: Cartilage stiffness was significantly reduced following Trypsin treatment, confirmed by both measurement methods (water jet device $p < 0.002$; material testing $p < 0.001$).

The results of the newly developed testing method correlated with those from a standard testing protocol ($r=0.659$). After 50s of fixed deformation using the materials testing device, native cartilage carried 50% of the initial load while degenerated cartilage carried less than 5% of the initial load.

	Water Jet System	Material Testing	Cartilage Thickness
Femur medial, native	24.9±5.2	35.7±4.4	1.09±0.24
Tibia, lateral, native	23.7±2.4	34.9±5.2	0.97±0.28
Femur, lateral, degenerated	11.0±2.0	23.3±7.2	0.84±0.14
Tibia, medial, degenerated	8.5±2.0	23.9±6.1	0.92±0.35

Table 1. Comparison of intact and degenerated cartilage stiffness measured by water jet system and material testing system in N/mm (mean±sd), cartilage thickness in mm (mean±sd).

DISCUSSION & CONCLUSIONS: The study reports that the water jet system clearly allows differentiation between native and degenerated cartilage samples. The lower stiffness measurements using the water jet system may be attributed to the lower applied forces and depth of penetration that measures only the superficial tissue layer. The stiffness values were well within the range of those previously reported using the arthroscopic system [4].

Compared to mechanical indentation testing, this new technique appears to minimize the risk of surface damage of the cartilage during mechanical loading. The system is extremely sensitive to testing of soft tissues. It may therefore be considered a valuable tool in the arthroscopic diagnosis of cartilage lesions. The water jet system provides an alternative to the existing indentation techniques with their inherent invasiveness.

REFERENCES: [1]Lyyra T et al.: *Med. Eng. Phys.* 17:395-9, 1995; [2]Lyyra T et al.: *Phys. Med. Biol.* 44:525-35, 1999; [3]Mow VC et al.: *J. Biomech.* 22:853-61, 1989; [4]Athanasiou KA et al.: *J. Orthop. Res.* 9:330-40, 1991