INTRODUCTION
Articular cartilage is highly inhomogeneous and anisotropic material. Biomechanical properties of cartilage show topographical variation in different joint areas [1]. Also depth-dependent differences in cartilage stiffness have been reported [2]. However, variation of Poisson’s ratio as a function of tissue depth is still unknown. In this study, depthwise mechanical properties of bovine patellar cartilage were characterized using biomechanical testing and direct measurement of Poisson’s ratio.

MATERIALS AND METHODS
Patellar osteochondral plugs (dia.=9 mm) of skeletally mature bulls (n=3) were prepared within 2 hours post mortem for biomechanical testing. In each plug, a cylindrical cut was made from cartilage surface to cartilage-bone interface with a biopsy punch (inner dia.=2.7 mm). The plug was mounted on a biopsy mold with O.C.T. compound and frozen at -20°C. After freezing cartilage surface was trimmed flat with a cryomicrotome and cartilage layer from surface to bone was cut into successive slices (thickness 192±25μm, 10-12 slices/animal). Every section from one animal, and three tissue layers (superficial, middle, deep slices) from 2 other animals, were characterized using mechanical and optical measurements.

Poisson’s ratio was determined using a direct microscopical method [3]. The lateral borders of the disk were determined with a segmenting algorithm and the change in the average diameter of the cartilage section, under unconfined compression at equilibrium (offset 5%, step 5%), was measured (1.93μm resolution).

Mechanical properties of cartilage slices were determined in unconfined compression geometry using a stepwise stress-relaxation technique (step 5%, up to 20% strain) and dynamic compression with multiple loading frequencies from 0.005 to 1 Hz (offset 20%, amplitude 3 μm). Young’s modulus confirm that structural inhomogeneity of the tissue creates a cartilage surface to subchondral bone. Our results on Poisson’s ratio and Young’s modulus confirm that structural inhomogeneity of the tissue creates a cartilage matrix with spatially highly variable elastic properties. For Poisson’s ratio through the cartilage depth was determined using direct optical measurements.

RESULTS
All measured parameters showed significant depth-dependent variation. The lowest Poisson’s ratios were measured in the superficial (0.07±0.05) and deep (0.12±0.06) cartilage layers (Fig. 1 and Table 1). Due to lift-off superficial slice could be tested only with frequencies up to 0.05 Hz. Superficial cartilage tissue behaved highly viscously when tested dynamically and, therefore, only low frequencies could be used without platen-tissue lift-off. Superficial and deep layers, but not the middle layer, showed frequency related increase in E<sub>mod</sub> and decrease in phase shift (Fig. 2).

DISCUSSION
In this study, variation of the moduli, and, for the first time, of the Poisson’s ratio through the cartilage depth was determined using direct optical measurements. All material properties showed spatial variations from cartilage surface to subchondral bone. Our results on Poisson’s ratio and Young’s modulus confirm that structural inhomogeneity of the tissue creates a cartilage matrix with spatially highly variable elastic properties. For Poisson’s ratio the exact structure-function relationship is still open. Knowledge of the depth-dependent variation in the material properties of the cartilage matrix is necessary for a realistic theoretical model of cartilage mechanical behavior.

REFERENCES

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