INTRODUCTION
It is generally believed that mechanical overloading is one of the major causes for the onset of cartilage degeneration. The first goal of this study was to determine the influence of cartilage thickness on the prevalence and the location of collagen damage after mechanical overloading. The second goal of this study was to determine the cause and nature of this collagen damage. It was hypothesized that initial cartilage damage involves loosening of interfibrillar bonds between the collagen fibrils, while the fibrils themselves remain intact until severe degenerative changes are induced [1,2]. In this study both the maximal shear strains along the collagen fibrils and the fibril strains were tested as possible candidates for causing collagen damage during mechanical overloading.

METHODS
Ten 8.5 mm osteochondral plugs were loaded 5 times with a spherical indenter (r=2 mm) with 25 N in 19.5 seconds. Coll II degradation was evaluated histologically using antibodies against denatured coll II (Col2-3/4M) [3]. The shear strains along the collagen fibrils and the fibril strains were computed with a fibril-reinforced poroviscoelastic swelling FEA-model [4]. In this model AC was assumed as biphasic, consisting of a solid and a fluid phase. The solid phase consisted of a swelling non-fibrillar part, which contains mainly proteoglycans, and a fibrillar part representing the collagen network. For the non-fibrillar part a compressible neo-Nookean model was used. The swelling behavior was implemented as a combination of osmotic swelling and chemical expansion. The fibrillar part consisted of large primary fibrils and smaller secondary fibrils. Bundles of primary fibrils extended perpendicular from the subchondral bone, splitting up close to the articular surface into fibrils curving to a horizontal course, flush with the articular surface (Fig. 1).

RESULTS
The thinnest samples showed the most damage in the experimental specimens, located at and below the articular surface. Intermediate samples were damaged below the surface and the thickest samples were undamaged (Fig. 2, 3).
fibrils fail at approximately 30.9% strain and that the fibrils themselves start to rupture at a strain of approximately 27.5% (Fig. 5).

DISCUSSION

Two mechanisms by which collagen damage can be initiated were found: (1) breaking of the entwinements between fibrils due to excessive shear strain along the collagen fibrils, and (2) breaking of the fibrils themselves due to excessive fibril strains. Probability and location of collagen damage after mechanical overloading are highly dependent on cartilage thickness. These findings strongly support the hypothesis that the earliest change in the collagen matrix integrity is loosening of the bonds between the large fibrils, and not rupture of the fibrils themselves.

REFERENCES

5. Benninghoff A, Form und Bau der Gelenkknorpel in ihren Beziehungen zur Funktion., Z Zellforsch, 2:783-862 (1925)