INTRODUCTION:
Not only cartilage degeneration but also sclerosis and stiffening of subchondral bone are known to be present in osteoarthritis (OA) [1]. Earlier studies have demonstrated that ultrasound reflection from the cartilage surface decreases during OA development [2]. Furthermore, ultrasound reflection from the cartilage-bone interface has been found to increase in experimentally induced OA [3]. However, it is not known if that is the case in spontaneous cartilage degeneration.

The main aim of this in vitro study was to investigate quantitatively the changes in ultrasound reflection from the cartilage-bone interface during cartilage degeneration using high resolution ultrasound imaging. Ultrasound reflection from overlying cartilage surface and attenuation in cartilage layer were also measured, and their effect on the results was investigated. Furthermore, cartilage compressive modulus was measured as a reference.

MATERIALS AND METHODS:
Osteochondral samples (n=32, dia.=16 mm) were prepared from the bovine patellae (1-3 years old) with normal or degenerated cartilage appearance. Quantitative ultrasound 2D-images (Dermascan-C 20 MHz ultrasound instrument, Cortex Ltd., Denmark) were acquired for all samples (line resolution =76 µm, sampling frequency =250 MHz).

Subsequently, small cartilage plugs (dia.=4 mm) were detached from the subchondral bone. Ultrasound attenuation and compressive modulus were measured for those plugs using the mecano-acoustic material testing instrument equipped with a 20 MHz transducer [4,5]. Finally, the degenerative grade of each sample was histologically determined using the Mankin scoring method [6], and the samples were divided into two groups according to their Mankin score: intact (Mankin score = 0, n=11) and degenerated (Mankin score = 1-10, n=21).

Ultrasound reflection from the cartilage-bone interface was quantified by calculating the ultrasound reflection coefficient in time-domain (IRC) and a coefficient in frequency domain (IRC (dB), frequency band 8-12 MHz) [2].

Mechanical stiffness was quantified by calculating the dynamic modulus in unconfined compression geometry (protocol: 10% prestrain, modulus in unconfined compression geometry (protocol: 10% prestrain, 10% strain, 2 mm/s ramp speed). Dynamic modulus was determined as a stress per strain ratio instantaneously after 10% step.

In the calculation of reflection coefficients from the cartilage-bone interface (R and IRC), measured reflection from the cartilage surface in each sample was determined. Furthermore, attenuation in the cartilage samples was calculated both in time-domain (amplitude attenuation) and in frequency domain (integrated attenuation, frequency band 5-9 MHz). Finally, all reflection measurements from the cartilage-bone interface were corrected with the attenuation of the overlying cartilage as well as with cartilage surface reflection.

RESULTS:
Visually, an increase in echogenicity from the cartilage-bone interface and a decrease in echogenicity from the cartilage surface were observed in 2D ultrasound images of degenerated samples, as compared to intact ones (Fig. 1).

A statistically significant increase (p<0.05, Mann-Whitney U test) in ultrasound reflection from the cartilage-bone interface was observed in degenerated sample group (Fig. 2). Moreover, correlation between the Mankin score and R or IRC was statistically significant (r=0.37 and 0.40 for R and IRC, respectively, p<0.05). After correcting the reflection results from the cartilage-bone interface with the attenuation of the overlying cartilage as well as with the cartilage surface reflection, a significant increase in absolute values of ultrasound parameters was observed (Fig. 2), however, correlations between the Mankin score and R or IRC remained unchanged.

The mean values of cartilage dynamic modulus in intact and degenerated sample groups were 9.5±6.9 MPa and 1.6±2.4 MPa, respectively. This difference in dynamic modulus was also statistically significant (p<0.05, Mann-Whitney U test).

DISCUSSION:
In line with a recent study [7], ultrasound reflection from the cartilage surface diminished in degenerated cartilage. Similarly, cartilage dynamic modulus decreased significantly in degenerated cartilage. For the first time, we demonstrated that an increase in ultrasound reflection from the cartilage-bone interface in spontaneously developed cartilage degeneration can be quantitatively determined with high resolution ultrasound imaging. Furthermore, it was quantitatively revealed that ultrasound attenuation in the overlying cartilage has a significant effect on the reflection values from the underlying bone. In order to determine the absolute reflection from the cartilage-bone interface, cartilage thickness and attenuation, as well as surface reflection, should be known. For diagnostic (in vivo) use, however, cartilage thickness, possible to determine with ultrasound [4], with a constant attenuation coefficient may be acceptable to correct the ultrasound reflection measurements from the cartilage-bone interface.

In summary, quantitative 2D ultrasound imaging enables detection of subchondral changes known to represent one of the first signs of OA. From a clinical point of view this is particularly important as these changes are currently impossible to diagnose during arthroscopy. By combining measurements of cartilage thickness, ultrasound reflection from the articular surface and from the cartilage-bone interface, more sensitive and quantitative diagnosis of early OA or follow up of surgical cartilage repair could be possible. For these purposes, an arthroscopic ultrasound instrument with acceptable measurement reproducibility is desirable.

REFERENCES: