INTRODUCTION: It has been reported that non-invasive ultrasonography (US) of the knee joint predicts better the outcome from diagnostic arthroscopy than conventional Noye’s arthroscopy [1]. In general, non-invasive US is cheap, fast and widely available imaging method for diagnostics of early OA changes. Furthermore, US does not involve ionizing radiation. However, so far non-invasive US has been concentrated on qualitative or semi-quantitative grading of OA changes only in articular cartilage (AC). In this study, a potential of quantitative non-invasive knee US for detecting changes in femoral subchondral bone related to knee OA was investigated. Subchondral bone areas were quantitatively analyzed from US images and compared with conventional radiography using Kellgren-Lawrence (K-L) grading scale [2], and with arthroscopy using Noye’s grading scale [3].

METHODS: The study involved 39 non-rheumatoid patients (15 women and 24 men, mean age = 52 years (range 37-73 years), mean body mass index = 27.5 (range 24-35)) referred to a knee arthroscopy because of knee pain. Before the arthroscopy was performed, all patients underwent non-invasive knee US examination. Ultrasonograms from medial and lateral femoral condyles as well as from intercondylar notch area (sulcus) were saved in DICOM format for later analysis. Conventional knee radiographs were available from 31 patients. A custom-made Matlab script (The MathWorks Inc., Natick, MA, USA) was applied in US image analysis. First, the regions-of-interest (ROI) in femoral medial (MED), sulcus (SULC) and lateral (LAT) subchondral bone areas were semi-automatically segmented (Fig. 1). The width of the rectangular ROI was set to 20 pixels (~ 1.39 mm) and the initial height to 50 pixels. The bone profile vector of mean gray-level intensity values was obtained by averaging values of each horizontal row in the segmented ROI. In order to compare the intensity values between patients, the bone profile vector was normalized by dividing all values by the maximum value. Subsequently, the profile vector was cut to start from the maximum value. Thus, the final height (i.e. the length of the vector) of the ROI was reduced to 25 pixels (~ 1.74 mm). Furthermore, 5 consecutive uniform bone depth levels were defined (Fig. 1A). The mean of each level and overall mean of the entire profile (level all) were calculated (Fig 1A). Finally, the total femoral bone profile vector and mean values in all depth levels were calculated for each patientconstituting an average of site-specific data (MED, SULC, LAT).

In the arthroscopic examination, the AC degenerative stage in femoral MED, SULC and LAT were graded by six-step Noye’s semi-quantitative grading scale. The total femoral arthroscopic score (FAS1) ranging from 0 to 18 was obtained by summing of all three site-specific scores. For the statistical analysis, the FAS1 was equally divided into three-step score (FAS2) as well as site-specific Noye’s score. The knee radiographs were evaluated by the K-L grading system varying from 0 to 4. The statistical analysis was conducted with SPSS software (ver. 16, SPSS Inc., Chicago, IL, USA). The normalized mean gray-level intensities of different bone depth levels were correlated with arthroscopic site-specific, FAS1 and K-L scores using Spearman’s correlation analysis. Unpaired t tests were conducted for different bone levels using FAS2 grouping 1 and 2, K-L grouping 0 and 1 and site-specific arthroscopic groupings. Tested groups were selected according to statistically sufficient number of data.

RESULTS: Qualitatively, an increase in subchondral bone normalized US intensity values were observed as OA progressed (Fig. 1B). Quantitatively, statistically significant correlations were found especially between normalized US mean intensity in subchondral bone depth level 2 and FAS1 (Fig. 2A) or K-L grading (Fig. 2B). Statistically significant differences were observed between normalized US mean intensity values in different bone depth levels and FAS2 grades 1 vs. 2 (Fig. 2C), as well as K-L grades 0 vs. 1 (Fig. 2D). In site-specific US results, most of the intensity variations were detected in MED and SULC areas, whereas in LAT area there were no significant differences in intensity values as OA progressed.

DISCUSSION: Current in vivo results confirmed the earlier in vitro findings [4] that the ultrasound reflection and backscattering from the subchondral bone increases in OA. This is most probably explained by the bone sclerosis, in which the bone density increases, thus also increasing the ultrasound reflection from the cartilage-bone interface.

The findings of this study are important as it has been earlier reported that AC changes can be evaluated with non-invasive US [5]. In the future, combined quantitative analysis of AC and subchondral bone from US data may provide even more sensitive indicator of early OA changes.