INTRODUCTION: It has been reported that non-invasive ultrasonography (US) of the knee joint predicts better the outcome from diagnostic arthroscopy than 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. Ultrasound images 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 patient as an average of site-specific data (MED, SULC, LAT).

In the arthroscopic examination, the AC degenerative stage of the entire 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 each patient an average of site-specific data (MED, SULC, LAT) 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 patient as an average of site-specific data (MED, SULC, LAT).

In the arthroscopic examination, the AC degenerative stage in femoral subchondral bone areas were semi-automatically segmented (Fig. 1). 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 patient as an average of site-specific data (MED, SULC, LAT).

Figure 2. Relationship between normalized mean gray-level intensity values of femoral bone level 2 and A) FAS1 or B) radiographic K-L grade. Normalized mean gray-level intensity values in different bone depth levels using grouping C) FAS2 grade 1 and 2 or D) radiographic K-L grade 0 and 1.

SIGNIFICANCE: For the first time, this study showed that the quantitative non-invasive knee US is suitable for evaluation of OA changes in knee femoral subchondral bone.

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