Comparison Of Annual Changes In Knee Articular Cartilage Thickness Between The Osteoarthritis Side And The Contra-lateral Side Measured By B-mode Ultrasonography With Mechanical 3d Scanning In Osteoarthritis Patients

Satoru Ohashi, M.D., Ph.D.1,2, Takumi Nakagawa3, Shuji Taketomi2, Hiroshi Inui2, Kumiko Ono2, Hiroyuki Oka4, Kozo Nakamura5, Sakae Tanaka2.  

1Department of Orthopaedic Surgery, Sagamihara Hospital, National Hospital Organization, Sagamihara, Japan, 2Department of Orthopaedic Surgery, Faculty of Medicine, University of Tokyo, Tokyo, Japan, 3Department of Orthopaedic Surgery, Teikyo University School of Medicine, Tokyo, Japan, 4Department of Joint Disease Research, 22nd century Medical Research Center, Faculty of Medicine, The University of Tokyo, Tokyo, Japan, 5Rehabilitation Services Bureau, National Rehabilitation Center for Persons with Disabilities, Tokorozawa, Japan.


Introduction: We developed a method for measuring articular cartilage thickness (Tc) by B-mode ultrasonography (US) with mechanical 3-dimensional (3D) scanning [1], allowing objective extraction of the cartilage area from US images using active contour models [2]. This study aimed to measure Tc by 3D B-mode US in osteoarthritis (OA) patients at 1-year intervals, evaluate changes in Tc at the medial femoral condyle and compare these results between the osteoarthritis side and the contra-lateral side.

Methods: Subjects comprised 15 female patients with unilateral OA of the knee (mean age, 72.5 years; range, 60-86 years). Kellgren-Lawrence grades of affected knees were as follows: Grade 1, 3 knees; Grade 2, 7 knees; Grade 3, 5 knees. US image acquisition for the affected knees was performed at baseline and at the 1-year follow-up. A B-mode 10.0-MHz linear US probe (UST-5411; Hitachi-Aloka Medical, Tokyo, Japan) connected to a US device (Prosound Alpha 6; Hitachi-Aloka Medical) was attached to a probe scanner that included a holding arm, enabling the US probe to move on the surface of the flexed knee (Fig. 1A). The medial surface of the affected knee and the contra-lateral knee was scanned using the US probe with the knee flexed at 120° (Fig. 1B), so the cartilage surface of the femoral condyle could be visualized on US. The total angle of arm rotation was 80° and 101 US B-mode images were acquired in 0.8° increments (Fig. 2A). Slice images were aligned in 3D in the proper position and orientation. Cartilage area of every third US image was extracted using an active contour method with manual seeding on the border of the cartilage area (Fig. 2A-C). Cartilage areas of images next to the manually seeded images were automatically extracted by the active contour method based on cartilage border information from seeded images. A 3D voxel model was then generated and wrapped with a triangular mesh to create a virtual 3D solid model of the cartilage structure (Fig. 2D, E). The medial sulcus terminalis, the distinct notch at the tibio-femoral joint and the patellofemoral joint on the medial femoral condyle were identified in the 3D model. The 3D femoral cartilage model was fit to a cylinder and each femoral condyle was divided at 0°, 20°, 40°, and 60° from the sulcus terminalis to create three regions of interest (ROIs) (ROI-1, 0-20°; ROI-2, 20-40°; ROI-3, 40-60°) (Fig. 2D, E). The Tc measurement point in each ROI was allocated every 1 mm in the medial-lateral direction and every 1° in anterior-posterior rotation (total, 200 points in each ROI). Mean Tc of each ROI (Tc-US) was calculated and
compared between baseline and 1-year follow-up by paired t-testing for both the OA side and the contra-lateral side. In addition, mean annual change of each ROI (ΔTc-US) was compared between the OA side and the contra-lateral side by paired t-testing. Differences were considered significant for values of p<0.05.

**Results:** Color mapping images of US models at baseline (Fig. 3A) and at 1-year follow-up (Fig. 3B) for a representative OA patient are shown in Figure 3. For the OA side, Mean Tc-US was \(1.74 \pm 0.27\) mm, \(1.55 \pm 0.30\) mm, and \(1.54 \pm 0.27\) mm (ROI-1, -2, and -3, respectively) at baseline and \(1.64 \pm 0.27\) mm, \(1.41 \pm 0.36\) mm, and \(1.39 \pm 0.31\) mm at 1-year follow-up and Tc-US was significantly decreased in each ROI over a year (Fig. 4). For the contra-lateral side, Mean Tc-US was \(1.84 \pm 0.25\) mm, \(1.73 \pm 0.23\) mm, and \(1.65 \pm 0.24\) mm (ROI-1, -2, and -3, respectively) at baseline and \(1.81 \pm 0.24\) mm, \(1.69 \pm 0.24\) mm, and \(1.61 \pm 0.23\) mm at 1-year follow-up. Although ΔTc-US of the OA side was significantly higher than ΔTc-US of the contra-lateral side in each ROI (Fig. 5), Tc-US of the contra-lateral side was also significantly decreased over a year in each ROI (Fig. 4).

**Discussion:** In a past study using magnetic resonance imaging (MRI) [3], the annual reduction in mean Tc at the central medial femoral condyle was reported as 5.8% in the high-risk group. Another MRI study of OA patients [4] showed that Tc on the affected side was decreased compared with the non-affected side in the relatively posterior area of the medial femoral condyle. The results of our study using US (annual reductions in Tc-US for the OA side were 5.7%, 9.0%, and 9.7% for ROI-1, -2, and -3, respectively) seem compatible with these previous MRI studies. Based on the results that Tc-US of the contra-lateral side significantly decreased over a year as well as the OA side, attention should be given to the change of Tc on the contra-lateral side in knee OA patients. We believe that Tc measurement using US has potential in the screening and clinical evaluation of OA because of its non-invasiveness, lack of radiation exposure and relatively short examination time.

**Significance:** We examined changes to Tc at the medial femoral condyle of OA patients using 3D-US, detecting significant reductions over a year both on the OA side and on the contra-lateral side. This imaging modality may prove useful as a screening test or for relatively inexpensive, quick and non-invasive follow-up of OA.
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**Figure 4**

![Graph showing Tc-US (mm) for different ROIs and conditions.](image)

**Figure 5**

![Graph showing ΔTc-US (mm) for different ROIs and conditions.](image)