Non-invasive Assessment of 3D Load Distribution over the Femoral Articular Cartilage after Medial Meniscectomy
- Experimental T2 Mapping Study in Porcine Knee -

INTRODUCTION

The meniscus plays an important role in the biomechanical knee function. Previous experimental and clinical studies showed that meniscectomy results in significant increase of local load transmission and leads to degeneration of the articular cartilage in the knee joint. However, there has been no methods which allows three-dimensional (3D) assessment of load distribution in the knee articular cartilage after meniscectomy or meniscus injuries without invasiveness. Recent studies of MR imaging showed cartilage T2 mapping is closely related with cartilage matrix and water content. Responsiveness of articular cartilage to compressive loading by T2 may indicate pressure distributions on the cartilage, via evaluation of dynamic changes in the collagenous architecture or water influx or efflux through cartilage 1-3.

The purpose of this study is to assess influence of medial meniscectomy on 3D T2 mapping of the femoral cartilage in the porcine knee joint, using a custom-made non-metallic pressure device which allowed MR imaging under variable loading magnitudes or knee alignments.

METHODS

Five normal porcine knee joints, harvested en bloc with intact capsules and surrounding muscles, were imaged using the custom-made pressure device and 3.0T MR imaging system. First, sagittal 3D-FIESTA-C images and sagittal T2 map images were obtained in the neutral alignment without external loading (Condition N), under mechanical compression of 140 N corresponding to approximately one-third of the body weight (Condition L), and under the same loading conditions as in Condition L with the knee at 10° varus alignment (Condition V) (Fig.1). Then, the joint capsules were opened and the medial meniscus was resected with a scalpel, carefully not to damage the articular cartilage. After meniscectomy, the capsules were closed and the knee joint was loaded in the same conditions as before (Condition V).

In the image analysis, 3D articular surface model and meniscus surface model was reconstructed from the high-resolutional FIESTA-C sequence images, and T2 color map was overlaid on the 3D surface model by using the custom-made semi-automatic software (Baum 3D). The region of interest (ROI) was manually defined on the femoral cartilage covered by the medial and lateral meniscus, which was divided into 12 ROIs (Fig.2). The decrease of mean T2 value at each ROI under the same loading conditions as before meniscectomy was calculated as (values in Condition N - values in each condition) / values in Condition N. The decrease of T2 before and after meniscectomy was compared at each condition.

RESULTS

At medial part in Condition L, large decreases of T2 were seen at M1,M2, and M5 (anterior/mid areas) before meniscectomy, and at M3,M5, and M6 (mid/posterior areas) after meniscectomy (Fig.3). There were significant differences at M1 and M6 (before/after; M1:9.8%/4.3%, M6:4.0%/11.4%) (p<0.05). There was no significant difference at the lateral ROIs.

At medial part in Condition V, large decreases of T2 before meniscectomy were mainly seen at M2 and M5 (mid areas) (Fig.4). After meniscectomy, large decrease areas of T2 were shifted to M3 and M6 (posterior areas), and there were significant differences at M1, M2, M4 and M6 (before/after; M1:8.7%/2.5%, M2:20.8%/2.1%, M4:8.0%/1.5%, M6:7.2%/18.7%) (p<0.05). At the lateral part, after meniscectomy the decrease rate was significantly smaller at L3 and L6 (before/after;L3:8.2%/3.6%, L6:8.1%/2.8%) (p<0.05).

DISCUSSION

Previous studies indicated that T2 changes under loading were significantly related with contact pressure on the cartilage 4. The present results suggested that medial meniscus resection may induce shift of stress concentration to the posterior- medial part of femoral articular cartilage, especially at varus knee alignment which was often seen in patients with knee osteoarthritis.

One of the limitations of this study was the structure of porcine knee in which knee full extension is less than 0 degrees. Therefore, the environment of porcine knee may differ from that of human knee, and further studies including the cadaver or human knee may be necessary to assess the change of load distribution more realistically.

Fig.3 Decrease of T2 value before/after meniscectomy in Condition L.

Fig.4 Decrease of T2 value before/after meniscectomy in Condition V.

REFERENCE