Articular Sliding Contact Behavior at Tibiofemoral Joint During In Vivo Dynamic Activity

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Introduction. The tibiofemoral joint exhibits sliding movement during functional activities. Regarding this phenomenon, the contact path length during running in the ACL reconstruction knee have been reported1). There is no report on showing the distribution of the sliding distance on the cartilage surface. In addition, since material wear generally depends on contact pressure and sliding speed2), it is necessary to consider the sliding speed (or sliding distance) for cartilage wear. The purpose of this study was to evaluate sliding behavior by tracking contact point path between femoral and tibial cartilage layers during in vivo dynamic activity.

Methods. In vivo knee kinematics data was assumed to be measured using a 2D/3D image matching technique4). Three-dimensional femoral and tibial bone models created from CT scan data were fitted to serial X-ray images captured at a constant time interval. Articular cartilage layer models (in other words, a point cloud discretizing the outer articular surface) were produced from MRI scan of the femur and tibia, then registered to the host bone models. If the cartilage models interfere with each other in a certain time frame $t_0$, it is determined as a contact, and the interference area is determined as the contact area. Then, if a certain point on the tibial cartilage model in the contact area is in contact in the next time frame $t_1$, it is judged that the point has been in contact with the femoral cartilage from $t_0$ to $t_1$. For the point judged to be in contact, the distance from which the femoral cartilage moved relative to the tibial cartilage was defined as the contact travel distance. If this distance was zero, a pure rolling would have occurred. Throughout the entire frames of X-ray images, contact travel distance was evaluated for each point that was judged to be in contact. Three subjects performed weight-bearing squatting before and after anterior cruciate ligament (ACL) injury. Contact travel distance during flexion of the knee up to 30° was cumulated and compared before and after ACL injury.

Results and discussion. Figure 1 shows the cumulative contact travel distance distribution in the initial stage of squatting of one subject. The range of the color scale is common before and after injury. Table 1 shows the maximum cumulative contact travel distance at the medical and lateral compartments and the difference in this maximum distance between before and after ACL injury. The average of the maximum cumulative contact travel distance was 18.3 mm at the medial compartment, 7.9 mm at the lateral compartment before injury, 19.9 mm at the medial, and 13.7 mm at the lateral after injury. Comparing the medial and lateral compartments, the cumulative contact travel distance was larger at the medial before and after injury. In the comparison before and after the injury, the cumulative contact travel distance was larger at the two compartments after injury, especially on the lateral. It has been reported that ACL injury is a risk factor of osteoarthritis (OA). In this study, the contact movement distance was larger in the ACL-injured knee, and the increase in contact travel distance was more remarkable in the lateral compartment than in the medial compartment. The mechanism of onset and development of OA in ACL-deficient knees can be discussed using this result.

Fig. 1 Distribution of cumulative contact travel distance on the tibial articular surface of subject #1.

Table 1 Maximum cumulative contact travel distance.

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<tr>
<th>#</th>
<th>Lateral</th>
<th>Medial</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before</td>
<td>After</td>
</tr>
<tr>
<td>#1</td>
<td>4.1</td>
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<tr>
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References.