POSTERIOR CRUCIATE LIGAMENT RECONSTRUCTION WITH MULTI-STRAND FLEXOR TENDON GRAFT FIXED WITH ENDobutton - BIOMECHANICAL EVALUATION USING CYCLIC LOADING TESTS -

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Introduction: The bone-patellar tendon-bone (BTB) graft has commonly been used in posterior cruciate ligament (PCL) reconstruction. However, clinical results after PCL reconstruction procedures have not always been consistent. Recently, a few studies have advocated several advantages of a novel less-invasive PCL reconstruction procedure, in which the multi-strand flexor tendon (FT) graft is tethered to an Endobutton with sutures (1, 2). However, there have been no biomechanical studies to validate this procedure. It is necessary to biomechanically evaluate this procedure because high loads are exerted on the reconstructed PCL. Currently, cyclic loading tests have been established to evaluate ligament reconstruction procedures (3, 4). Concerning PCL reconstruction procedures, Bergfeld et al (5) recently reported a biomechanical study to compare two procedures with the BTB graft using 72 cycles of repetitive loading. However, studies have not been conducted using cyclic loading tests to compare PCL reconstruction procedures between the FT graft and the BTB graft. The purpose of this study is to compare biomechanical behaviors of the knee with the PCL reconstruction procedure using multi-strand FT graft and an Endobutton to the two standard PCL reconstruction procedures with the BTB graft, using cyclic loading of 5000 times.

Materials and Methods: Forty-five fresh-frozen hindlimbs from fully mature LWD pigs were used in this study. The flexor digitorum profundus tendon and the BTB preparation harvested from these animals were used as substitutes for the human hamstring and BTB grafts, respectively, according to our previous studies (3, 4). The 45 knee specimens were randomly divided into three groups of 15 specimens each. For each group, the PCL was resected and then reconstructed with one of the following three techniques. In Group A, two flexor tendons were sharply trimmed so that the cross-sectional area became 14 mm² and 7 mm² to simulate the human semitendinosus and gracilis tendons, respectively. Then, PCL was reconstituted with the doubled flexor tendon graft, which was fixed with 2 threads (ø6) and an Endobutton, proximally, and with 4 sutures (ø3) and a screw post, distally (FT-Button procedure). In Group B, each end of the 10-mm wide BTB graft with 25-mm long bone plugs was secured with an interference screw (BTB-tunnel procedure). In Group C, the femoral side of the same sized BTB graft was fixed with an interference screw, and the tibial bone plug was placed on the back of the tibia and secured with a 4.5-mm cortical screw and flat washer (BTB-inlay procedure) (5, 6). Each femur-graft-tibia (FGT) complex specimen was mounted on a tensile tester at 90 degrees of knee flexion. Anterior-posterior displacement of the tibia to the femur was measured with a differential transformer type transducer attached to the femur and tibia. The load and the displacement were continuously recorded in a X-Y recorder. Each group underwent preconditioning (10 cycles of 50-N loads, and then 89-N load for 2 minutes), and then, was divided into 3 sub-groups of 5 complexes each. One sub-group underwent 5000 times (0.28 Hz) of cyclic loads with a constant peak value of 89 N (Load-controlled cyclic testing). Another sub-group underwent 5000 times (0.28 Hz) of cyclic displacements with a constant peak value of 3 mm (Displacement-controlled cyclic testing). The remaining sub-group did not undergo any cyclic testing. These peak values were chosen to simulate mechanical conditions during continuous passive knee motion. Finally, each specimen underwent tensile failure testing at a crosshead speed of 50 mm/min, after the complex was reduced to the zero-position. Statistical analyses were performed using ANOVA with Fischer’s PLSD test for post hoc multiple comparisons.

Results: (1) Load-controlled cyclic testing: The peak displacement value significantly increased over time in each group (p<0.05). The value at the 5000th cycle was significantly greater in Group A than in Groups B and C (p<0.05) (Figure 1-a). (2) Displacement-controlled cyclic testing: The peak load value significantly decreased over time in each group. The value at the 5000th cycle was significantly less in Group A than in Groups B and C (p<0.05) (Fig. 1-b). In addition, the peak load value in Group B was significantly less than that in Group C. (3) Tensile failure tests: Before cyclic tests, the ultimate load (579.7 ± 33.4 N) and the linear stiffness (27.3 ± 3.8 N/mm) of Group A were significantly (p<0.01) less than those of Groups B (865.5 ± 18.3 N, 60.0 ± 4.0 N/mm) and C (863.1 ± 37.5N, 72.4 ± 8.1 N/mm). The linear stiffness of Group B was significantly (p<0.05) less than that of Group C. In each group, the ultimate load was not affected by each type of cyclic loading. The posterior laxity (the posterior displacement induced by a 134-N load) after load-controlled cyclic testing was significantly greater in Group A than in Groups B and C (p<0.01) (Table 1). Discussion: Both the peak displacement and the peak load at the 5000th cycle were changed to a significantly greater degree in the PCL-reconstructed knee with the FT-Button procedure than in the knees with the BTB-tunnel and BTB-inlay procedures. These results suggested that plastic deformation of the FGT complex reconstructed with FT-Button procedure occurs more easily due to cyclic loading than the complex reconstructed with the two BTB procedures. Interestingly, the peak load at the 5000th cycle was significantly higher in the PCL-reconstructed knee with the BTB-inlay procedure than in the knee with the BTB-tunnel procedure. This result indicated a superiority of the BTB-inlay procedure. This study demonstrated that mechanical conditions of cyclic testing should be carefully chosen to compare various PCL reconstruction procedures, because they significantly affect the results. As to clinical relevance, it is considered that, after PCL reconstruction with the FT-Button procedure, postoperative management accompanied with cyclic loading should be avoided until the graft is fixed with granulation tissues within the bone tunnel.

Fig. 1 Peak displacement during load-controlled cyclic testing (a) and peak load during displacement-controlled cyclic testing (b).

Table 1. Posterior laxity (mm) before and after cyclic testing

<table>
<thead>
<tr>
<th></th>
<th>Group A</th>
<th>Group B</th>
<th>Group C</th>
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<tbody>
<tr>
<td>Before cyclic testing</td>
<td>4.3 ± 0.9</td>
<td>2.4 ± 0.4</td>
<td>2.5 ± 0.8</td>
</tr>
<tr>
<td>After load-controlled cyclic testing</td>
<td>7.5 ± 0.4</td>
<td>3.9 ± 0.3</td>
<td>4.1 ± 0.2</td>
</tr>
<tr>
<td>After displacement-controlled cyclic testing</td>
<td>3.9 ± 0.3</td>
<td>2.7 ± 0.4</td>
<td>2.5 ± 0.4</td>
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Values are mean ± SD.


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