Bone Tunnel Widening After Anterior Cruciate Ligament Reconstruction Using EndoButton or EndoButton Continuous Loop

Martin Lind, M.D., Ph.D., Julian Feller, M.B.B.S., F.R.A.C.S., and Kate E. Webster, Ph.D.

Purpose: This study investigated the effect of the EndoButton CL (Smith & Nephew, Andover, MA) used for femoral graft fixation during anterior cruciate ligament reconstruction compared with an EndoButton with knot-fixed polyester tape on femoral and tibial bone tunnel widening and clinical outcome. Methods: A retrospective case-control study design was used. We compared 120 patients with EndoButton CL femoral fixation with 120 patients with an EndoButton with knot-fixed polyester tape. All patients had hamstring grafts and EndoButton femoral fixation and tibial fixation with a 7 × 30-mm metal interference screw. Tunnel widening was measured on anteroposterior (AP) and lateral radiographs at 12 months’ follow-up. The largest tunnel width was measured for the femoral tunnel and in the tibial tunnel above the interference screw. Clinical outcome was assessed by objective and subjective International Knee Documentation Committee scores and KT-1000 (MEDmetric, San Diego, CA) knee laxity measurements. Results: Femoral tunnel widening in the EndoButton group was 46.2% and 38.5% on the AP and lateral radiographs, respectively, and tibial tunnel widening was 24.9% and 33.2%, respectively. Femoral tunnel widening in the EndoButton CL group was 38.7% and 28.2% on the AP and lateral radiographs, respectively, and tibial tunnel widening was 10.9% and 23%, respectively. The EndoButton CL widening was lower for both femoral and tibial tunnels (P < .01). There were no differences between the groups for any of the clinical scores or KT-1000 knee laxity. Conclusions: This study showed that femoral anterior cruciate ligament graft fixation with an EndoButton and continuous polyester loop compared with an EndoButton with knot-fixed polyester tape reduced the radiographic tunnel widening at 1 year for both the femur and tibia. The reduction in tunnel widening was not associated with differences in clinical outcome with respect to International Knee Documentation Committee scores or KT-1000 knee laxity measurement. Level of Evidence: Level III, retrospective comparative study. Key Words: ACL reconstruction—Tunnel widening—EndoButton—Clinical outcome—Radiographic analysis.

Tunnel widening after anterior cruciate ligament (ACL) reconstruction is a well-described phenomenon.\textsuperscript{1-3} The basis of tunnel widening is multifactorial, with several possible mechanical and biological contributing factors.\textsuperscript{1,4} These are tunnel positioning, graft fixation method, resorbable implant degradation, access of joint fluid to the graft-bone interface, and bone quality. Suspensory graft fixation results in a more elastic graft construct and may contribute to the so-called bungee effect, which has been suggested to contribute to tunnel widening.\textsuperscript{1,4-6} Tunnel widening is more frequent when indirect or cortical fixation techniques, such as the EndoButton (Smith & Nephew, Andover, MA) or fixation posts, are used compared with fixation methods closer to the joint.\textsuperscript{5} Tunnel widening after ACL reconstruction can be clinically problematic, with excessive tunnel widening resulting in increased knee laxity and poor bone stock for revision reconstruction procedures.\textsuperscript{1,5} A previous EndoButton technique used a polyester tape that needed to be tied at the desired length.
However, biomechanical studies showed slippage of the polyester tape of 2 to 4 mm. This could lead to increased laxity and the bungee effect of the graft-implant complex, which in turn could contribute to tunnel widening. To address some of these concerns, EndoButton fixation with a continuous polyester loop was introduced. Biomechanical studies have shown less slippage of the EndoButton with a continuous loop compared with the EndoButton with knot-fixed polyester tape.

Previous studies that showed significant radiographic tunnel widening with EndoButton fixation also used suspensory fixation on the tibia. Webster et al. showed femoral tunnel widening of 48% after 1 and 2 years’ follow-up. Clatworthy et al. showed up to 100% femoral tunnel widening. At present, it is unknown whether the optimized implant (EndoButton CL), which is very stiff and allows very limited graft slippage, is able to reduce tunnel widening and graft laxity.

The aim of this study was to compare radiographic bone tunnel widening and early clinical outcomes in patients with hamstring ACL reconstruction and femoral graft fixation with either an EndoButton CL or an EndoButton with knot-fixed polyester tape. A case-control study design was used. It was hypothesized that using the EndoButton CL would reduce femoral tunnel widening and anterior knee laxity compared with the EndoButton with knot-fixed polyester tape.

METHODS

Patients

The study included 120 patients meeting the inclusion criteria who had received semitendinosus and gracilis 4-strand hamstring grafts fixed with an EndoButton CL and 120 patients who had the same graft fixed with an EndoButton and knot-fixed polyester tape (Fig 1). All patients had metal interference screw graft fixation in the tibia. The inclusion criteria were as follows: primary ACL reconstruction with 4-strand hamstring graft, follow-up at 12 months with radiographic examination, no previous cruciate ligament damage to the operated knee, no collateral ligament injury greater than grade II laxity, and no radiographic evidence of osteoarthritis. The exclusion criteria were patellar tendon graft and lack of clinical or radiographic follow-up. The group who underwent femoral fixation with the EndoButton and polyester tape (EndoButton group) was operated on between April 2004 and March 2006. The EndoButton CL femoral fixation group (EndoButton CL group) was operated on between May 2006 and May 2007. Demographic and clinical data were extracted from a database in which this information was prospectively collected and recorded. The 2 groups were similar with respect to age, gender, interval from injury to surgery, preoperative sports activity level, and preoperative occupational rating (Table 1).

Surgical Technique

All patients had ACL reconstruction with an arthroscopically assisted technique performed by the same experienced knee surgeon. Gracilis and semitendinosus tendons were harvested through a small incision over the pes anserinus. A transtibial technique was used for femoral drilling. An oblique tibial tunnel starting at the anterior edge of the medial collateral ligament and ending in the ACL tibial footprint ensured a shallow and posterior starting point for the femoral tunnel. In the EndoButton group the EndoButton for

**Table 1. Demographics**

<table>
<thead>
<tr>
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<th>EndoButton Group (n = 120)</th>
<th>EndoButton CL Group (n = 120)</th>
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<tbody>
<tr>
<td>Age [mean (range)] (yr)</td>
<td>29.7 (16-57)</td>
<td>27.6 (16-52)</td>
</tr>
<tr>
<td>Gender (F/M)</td>
<td>36/84</td>
<td>31/90</td>
</tr>
<tr>
<td>Time from injury to surgery [median (range)] (wk)</td>
<td>13 (1-821)</td>
<td>13 (1-899)</td>
</tr>
<tr>
<td>Preinjury sports activity level [median (range)]</td>
<td>100 (55-100)</td>
<td>95 (60-100)</td>
</tr>
<tr>
<td>Preinjury occupational rating [median (range)]</td>
<td>17 (0-59)</td>
<td>20 (0-57)</td>
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Femoral fixation was attached to the graft with a doubled 3-mm polyester tape tied with 5 throws of the square knot. In the EndoButton CL group the graft was placed in the loop. For both groups, a 4-strand graft was formed. A minimum 25 mm of the graft was placed in the femoral tunnel. The grafts were not pre-tensioned but were cycled 10 times in situ before tibial fixation. Tibial fixation in all patients was achieved with a 7 × 30 mm metal interference screw. The head of the screw was placed just inside the tibial cortex for optimal graft compression and fixation.

All patients followed the same accelerated rehabilitation protocol. The rehabilitation allowed full weight bearing from the first postoperative day and focused on early restoration of terminal extension and quadriceps function.

Evaluation

A Rosenberg-type anteroposterior (AP) radiograph and a lateral radiograph with the knee in full extension were obtained at 12 months’ follow-up. Tunnel widening was measured according to the method of L’Insalata et al. by measuring the widest tunnel diameter on AP and lateral radiographs. All measurements were performed by the same independent observer, who was an orthopaedic surgeon (M.L.). The radiographs were not blinded to group allocation.

For the femur, the widest diameter of the whole tunnel was measured with a digital caliper, and for the tibia, the widest diameter above the metal interference screw was measured. The measurements were made between the inner borders of the sclerotic margins (Fig 2). All measurements were corrected for magnification. Tunnel widening was expressed as a percentage of the diameter of the drill bit used to create the tunnel.

To determine intrarater reliability, 20 sets of radiographs were randomly selected and remeasured at a minimum of 2 weeks later.

All patients were seen for a 12-month clinical review performed by an independent research assistant before consultation with the treating surgeon. The following variables were recorded: objective International Knee Documentation Committee (IKDC) overall rank, subjective IKDC score, Noyes sports activity levels and occupational rating scores, KT-1000 (MEDmetric, San Diego, CA) measurement of the side-to-side difference in anterior knee laxity at 30 lb (135 N), and extension deficit by use of the heel height difference described by Sachs et al.

Statistics

The percent change in tunnel diameter at follow-up was compared between the EndoButton and EndoButton CL groups by use of an independent-samples t test. Categorical data were compared by use of χ² tests. Intraclass correlation coefficients were calculated to assess intraobserver reliability. Data are presented as mean (standard deviation [SD]).

Power analysis for the primary parameters was based on the following assumptions for SDs: tunnel
widening, 20%; subjective IKDC score, 12 points; and KT-1000 side-to-side difference, 2.0 mm. This enabled us to detect a difference of 8% or greater between the 2 groups for tunnel widening, 5 points for the IKDC subjective score, and 0.75 mm for anterior knee laxity with a power of 80% and $P$ value of .05.

RESULTS

Tunnel Widening

The tunnels in both the femur and tibia typically had well-demarcated sclerotic margins. In a few cases the margins were less clear, but in only 5 (4 in EndoButton group and 1 in EndoButton CL group) of 240 femoral tunnel views and 10 (4 in EndoButton group and 6 in EndoButton CL group) of 240 tibial tunnel views could the tunnel width not be determined. In the femur the typical appearance of the tunnels was conical in shape, with the widest part of the tunnel being close to the intercondylar notch tunnel opening. In the tibia the typical appearance was more cylindrical, with a narrowing near the level of the joint. The initial values of tunnel diameter were not significantly different between the groups and were 7.89 mm and 7.75 mm in the EndoButton and EndoButton CL groups, respectively.

The tunnel widening data for the femur and tibia in both groups are shown in Fig 3. Mean femoral tunnel widening was less on both radiographic views in the EndoButton CL group ($P < .01$). In this group there was 38.7% (SD, 17%) and 28.2% (SD, 19%) widening on the AP and lateral radiographs, respectively, compared to 46.2% (SD, 20%) and 38.5% (SD, 24%), respectively, in the EndoButton group.

For the tibial tunnel, widening in the EndoButton CL group was also significantly less for both radiographic views ($P < .01$). There was 10.9% (SD, 16%) and 23.0% (SD, 17%) widening for the AP and lateral views, respectively, in this group, compared with 24.9% (20%) and 33.2% (19%), respectively, in the EndoButton group.

Clinical Outcomes

The clinical assessment results at 1 year are summarized in Table 2. There was no difference in IKDC scores between the 2 groups. A rating of normal (A) or nearly normal (B) was given in 89% of patients in the EndoButton group and 82% in the EndoButton CL group. Subjective IKDC scores greater than 80 points were seen in 67% of EndoButton group patients and 73% of EndoButton CL group patients. No differences were found for the sports activity level or occupational rating scores. The KT-1000–measured side-to-side difference in anterior knee laxity was not different between the groups, with mean values of 1.3 mm (SD, 1.7 mm) and 1.5 mm (SD, 2.7 mm) for the EndoButton and EndoButton CL groups, respectively. The mean extension deficit was significantly less in the EndoButton CL group, at 0.3° (SD, 1.6°) compared with 1.7° (SD, 2.2°) in the EndoButton group ($P < .01$).

Measurement Reliability

Intraobserver variability for tunnel width measurements was satisfactory. The intraclass correlation co-

![TABLE 2. Clinical Outcome at 12 Months’ Follow-up](image)

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<tr>
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<th>EndoButton Group</th>
<th>EndoButton CL Group</th>
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<tbody>
<tr>
<td>IKDC subjective score</td>
<td>83.4 (35-100)</td>
<td>86.3 (21-100)</td>
</tr>
<tr>
<td>IKDC objective score (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>43.2</td>
<td>30.8</td>
</tr>
<tr>
<td>B</td>
<td>45.9</td>
<td>51.6</td>
</tr>
<tr>
<td>C</td>
<td>8.5</td>
<td>14.3</td>
</tr>
<tr>
<td>D</td>
<td>2.4</td>
<td>3.3</td>
</tr>
<tr>
<td>KT-1000 side-to-side</td>
<td></td>
<td></td>
</tr>
<tr>
<td>difference [mean (SD)] (mm)</td>
<td>1.3 (1.7)</td>
<td>1.5 (2.7)</td>
</tr>
<tr>
<td>Extension deficit [mean (SD)] (°)</td>
<td>1.7 (1.6)</td>
<td>0.3 (2.2)*</td>
</tr>
<tr>
<td>Sports activity level score [median (range)]</td>
<td>90 (20-100)</td>
<td>85 (20-100)</td>
</tr>
<tr>
<td>Occupational rating [median (range)]</td>
<td>16 (0-59)</td>
<td>20 (0-57)</td>
</tr>
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* $P < .01$ for comparison with EndoButton group.

![FIGURE 3. Tunnel widening data in both femoral and tibial tunnels presented as percent tunnel widening normalized to preoperative drill hole diameters. In the femur the widest point of the tunnel is measured. In the tibia the widest point above the metal screw is measured. Data are presented as mean values and SDs (error bars). Asterisks indicate a significant difference between the EndoButton and EndoButton CL groups ($P < .01$). (AP, anteroposterior projection; Lat, lateral projection.)](image)
efficient (ICC 2,1) was 0.91 and 0.94 for femoral AP and lateral radiographic measurements, respectively. For tibial measurements, the intraclass correlation coefficient was 0.77 and 0.96 for AP and lateral radiographic measurements, respectively.

**DISCUSSION**

The results of this study show that using an EndoButton CL femoral implant reduces the postoperative radiographic widening in both the femoral and tibial tunnels compared with an EndoButton with knot-fixed polyester tape. The stiffer and slippage-free EndoButton CL implant, therefore, seemed to have created a more favorable biomechanical environment, resulting in less tunnel widening at the 1-year time point. Reduced tunnel widening was also found in the proximal part of the tibial tunnel above the metal interference screw. A possible explanation for this finding could be that earlier healing of the graft to the femoral tunnel walls resulted in earlier overall stabilization of the graft in the joint, which subsequently also affected proximal tibial graft healing.

The intraosseous biomechanical properties of the EndoButton and knot-fixed polyester tape cannot be extracted from this study. However, we did not find increased knee laxity on KT-1000 measurements.

Minor knot slippage could, however, result in increased graft micromotion in the bone tunnels that could delay tendon-to-bone healing, resulting in a longer period of time during which tunnel widening can develop. Such a scenario is supported by both computed tomography (CT) and radiographic studies, which show that tunnel widening develops in the first 3 months postoperatively. Our laxity findings in the 2 study groups were similar to previous studies from our group and data from national registries for ACL reconstruction.

The lesser tunnel widening with the EndoButton CL implant did not appear to have any major impact on the measured clinical parameters. We did find a slightly lesser extension deficit in the EndoButton CL group, but this is of uncertain clinical relevance and the explanation for this difference is not readily apparent. It could be speculated that the reduced tibial tunnel widening resulted in less scar tissue formation at the tibial graft entry area, thereby resulting in a lesser extension deficit.

The development of tunnel widening appears to be related to the tendon–to–bone tunnel wall healing. Until a dense fibrous tissue anchors and stabilizes the graft tendon to the bone tunnel wall, micromotion of the graft tissue may result in bone remodeling that eventually leads to tunnel widening. Another theory is that synovial fluid is able to enter the graft-bone interface and cause adverse bone remodeling. If synovial fluid can enter the graft-bone interface, the increased levels of inflammatory cytokines shown to be present postoperatively could induce bone resorption.

In this study plain radiographs were used to assess tunnel widening. CT reconstructions and magnetic resonance imaging provide more detailed images of tunnel configurations. However, it was not feasible to use these more expensive techniques, given the number of subjects involved in this study. A good correlation between radiographic and CT scan–based tunnel widening measurements has previously been shown. Tibial tunnel diameter was shown to be well correlated between radiographic and CT scans, whereas femoral tunnel widening was moderately overestimated on radiographs compared with CT scans. Similarly, a good correlation between magnetic resonance imaging and radiographic tunnel widening measurements at 2 years’ follow-up was found by Jansson et al. One potential methodologic problem with our study design could be if the surgical technique had changed the tunnel positioning during the study period, resulting in different tunnel positions in the 2 study groups. However, the operating surgeon (J.F.) has used the same transtibial surgical technique for more than a decade. Therefore we do not believe that tunnel positioning should be different between the 2 study groups.

In addition, a retrospective study design such as ours does not generate as reliable data as prospective and randomized study designs. Our study only analyzes suspensory femoral fixation for its effect on tunnel widening. It would have been interesting to compare our data with aperture fixation methods.

**CONCLUSIONS**

Our study showed that femoral ACL graft fixation with the EndoButton CL reduced radiographically measured tunnel widening at 1 year for both the femur and tibia better than the EndoButton with knot-fixed polyester tape. The reduction in tunnel widening was not associated with differences in clinical outcome with respect to IKDC scores or KT-1000 knee laxity measurement.
REFERENCES


