Outcomes of ACL Reconstruction With Fixed Versus Variable Loop Button Fixation

BRENT T. WISE, MD; NICK N. PATEL, MD; GARRISON WIER, MD; SAMEH A. LABIB, MD

Abstract

Suspensory femoral fixation of anterior cruciate ligament (ACL) grafts with fixed loop button and variable loop button devices has gained popularity for ACL reconstruction. This study examined these 2 methods of fixation to determine their effect on graft laxity and patient-reported outcome scores. A database search was performed to identify patients who had undergone ACL reconstruction with either a fixed loop or a variable loop button technique performed by the primary surgeon. Lysholm, Tegner, and 12-Item Short Form Health Survey scores were obtained, and KT-1000 knee ligament arthrometer (MEDmetric, San Diego, California) mechanical knee testing was performed. Results were compared with the uninjured knee. Of the 112 patients who were identified, 91 met the study criteria. Of these patients, 57 completed KT-1000 knee testing, 33 in the variable group and 24 in the fixed group. The average KT-1000 value for the variable group was 0.38 mm, and the average for the closed group was 0.92 mm ($P = .19$; 95% confidence interval, -0.28 to 1.35). Among the 19 patients in the variable group and the 13 in the closed group who completed the subjective outcomes questionnaires, no statistically significant difference was found. Clinically lax knees (KT-1000>3 mm) were found in 6.1% and 12.5% of patients in the variable group and the fixed group, respectively ($P = .2$). The variable group had a rerupture rate of 4.7%, whereas the fixed group had a rerupture rate of 8.7% ($P = .21$). The study found no statistical difference in ACL graft laxity or postoperative functional outcomes between grafts fixed with the variable loop or fixed loop button technique. [Orthopedics. 2017; 40(2):e275-e280.]

The authors are from Emory University, Atlanta, Georgia.

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Correspondence should be addressed to: Brent T. Wise, MD, Emory University, 59 Executive Park S, Atlanta, GA 30329 (brent.wise@emory.edu).

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Anterior cruciate ligament (ACL) injury continues to be the most common serious injury of the knee seen by orthopedic surgeons. An estimated 50,000 to 175,000 primary ACL reconstructions are performed each year in the United States, and ACL reconstruction is the sixth most commonly performed orthopedic procedure. Many factors affect the overall outcome of ACL reconstruction. Among these, graft fixation and subsequent incorporation into the bony tunnels are considered essential for the stability of the reconstructed knee.

There are limited data specifying a superior graft fixation technique. Suspensory fixation with titanium button devices has gained popularity because of the simplicity of the procedure and the reliability and excellent tensile strength afforded by the devices. Suspensory fixation methods are broadly divided into fixed loop and variable loop systems.

Fixed loop button fixation devices include the EndoButton (Smith & Nephew, Andover, Massachusetts) and RetroButton (Arthrex, Naples, Florida). These fixed loop designs may not deploy successfully if the graft tunnel is too short to allow clearance of the device through the femur. Alternatively, a large loop may
lead to an inadequate amount of graft in the femoral tunnel. Variable loop systems, such as the TightRope RT (Arthrex) and the ToggleLoc with ZipLoop (Biomet Inc, Warsaw, Indiana), use a series of sutures that can be used as a pulley system to shorten the loop and deliver the graft to the end of the femoral socket for a tight fit. This technique reduces the approximation needed in measurements and allows the graft to be advanced farther into the femoral tunnel after the button “flips,” which is not possible with a closed loop fixation technique. Some authors suggest that this may lead to improved incorporation of the graft, given the larger interface for bone-tendon healing.\textsuperscript{11-13} Additionally, variable loop systems provide increased flexibility with tunnel placement, which can be useful for pediatric reconstructions and other unique applications, such as revision ACL or combined ACL and posterior cruciate ligament reconstructions.

Although multiple biomechanical studies have compared fixed and variable loop systems, limited data are available on clinical outcomes.\textsuperscript{8,14,15} This study examined these 2 methods of button fixation to determine their clinical effect on objective graft laxity and functional outcomes. The authors hypothesized that the variable loop fixation technique would result in improved objective measurements of graft laxity at follow-up because it allows a greater amount of graft to be drawn into the femoral tunnel and also that overall functional outcomes would be comparable between the 2 techniques.

**Materials and Methods**

**Subject Identification**

Patients who underwent ACL reconstruction with either the fixed loop button or the variable loop button surgical technique by the principal investigator (S.A.L.) between January 1, 2008, and December 31, 2012, were identified through a search of procedure codes. After a review of medical records, potential participants were contacted to determine eligibility. The primary surgeon predominately used the fixed loop technique from 2008 to 2010 and transitioned to primarily using the variable loop technique from 2011 to 2012.

**Inclusion Criteria**

Patients were included in the study if they (1) had ACL rupture and subsequent successful primary ACL reconstruction with either the fixed loop button or variable loop button device; (2) were 18 years or older; and (3) had no other illnesses that prevented them from ambulating normally (without the help of devices).

**Exclusion Criteria**

Patients were excluded from the study if they (1) were younger than 18 years; (2) had multiple ligamentous injuries or fractures; (3) had previous knee surgery, revision ACL reconstruction, or osteotomy performed at the time of ACL reconstruction; or (4) had ACL reconstruction with other modes of fixation on the femoral side.

**KT-1000 Analysis**

To test the integrity of the ACL graft, KT-1000 knee ligament arthrometer (MEDmetric, San Diego, California) analysis was performed after study initiation by an independent physical therapist who was blinded to the fixation method used on both knees of the participants. Specifically, KT-1000 testing allowed quantification of the anterior translation of the tibia in relation to the femur, and results were reported as a comparison between the operative and nonoperative sides. The KT-1000 test was performed by securing a device to the front of the knee, which was flexed at 25°, with the patient lying on his or her back. Both maximal force and 85 N force were used to pull at the front of the lower leg, and displacement of the knee was measured.

**Questionnaires**

A series of questionnaires and scales were used to evaluate each surgical technique based on subjective patient response. These instruments were administered either during an office visit or online and included the Lysholm questionnaire to assess postsurgical knee function and stability, the Tegner scale to measure pre- and postsurgical activity level, and the 12-Item Short Form Health Survey (SF-12) to evaluate current physical and mental health.

**Statistical Analysis**

Participants were grouped according to whether they had undergone the fixed loop button technique or the variable loop button technique, and descriptive data (mean±SD) were calculated for all variables. Unpaired 2-sample Student’s t test was used to compare primary outcomes: overall means for the KT-1000 test and Tegner, SF-12, and Lysholm scores. Chi-square analysis was performed to compare secondary outcomes: the proportion of ACL reruptures and clinically lax KT-1000 values (>3 mm). \( P \leq .05 \) was considered statistically significant.

**RESULTS**

**KT-1000 Testing**

A search of procedure codes identified 112 patients who underwent ACL reconstruction during the designated period by the primary investigator with either the variable loop (43 patients) or fixed loop (69 patients) technique. Of the 69 patients who were identified and had fixed loop reconstruction, 16 were excluded (including 6 with ACL rerupture). Of the 43 patients who were identified and had variable loop reconstruction, 5 were excluded (including 2 with ACL rerupture). Mean age for patients in the variable and fixed groups was 28.9 and 27.3 years, respectively (Table 1). The diagnosed rerupture rate after ACL reconstruction was 4.7% for the variable group and 8.7% for the fixed group (\( P=.21 \)). For those who met the criteria and agreed to participate, mechanical knee testing with KT-1000 analysis was performed on a total of 57 patients.
participants. Of these, 33 were in the variable group and 24 were in the fixed group. Mean KT value for the variable group was 0.38 mm (95% confidence interval, -0.16 to 0.92) and for the fixed group was 0.92 (95% confidence interval, 0.36 to 1.48) (Table 2). Mean difference between the 2 surgical groups was 0.54 mm (P=.19; 95% confidence interval, -0.28 to 1.35). For ACL grafts that were considered clinically lax (KT>3 mm), the variable group had a rate of 6.1% and the fixed group had a rate of 12.5% (P=.2).

**Subjective Outcomes**
Of the identified patients who underwent ACL reconstruction, 32 completed the Lysholm, Tegner, and SF-12 questionnaires (19 in the variable group and 13 in the fixed group). The findings are summarized in Table 3. For the Tegner activity scale, preoperative means for the variable and fixed groups were 8.00 and 6.92, respectively (P=.09), and postoperative means were 6.21 and 6.46, respectively (P=.61). Postoperative Lysholm knee scale means were 87.28 for the variable group and 91.31 for the fixed group (P=.37). The postoperative SF-12 health survey included mental health and physical health components. For the SF-12 physical component, mean scores were 53.18 and 54.89 for the variable and fixed groups, respectively (P=.33). Mean scores for the SF-12 mental component were 54.84 and 54.82 for the variable and fixed groups, respectively (P=.99).

**DISCUSSION**
This study directly compared the 2 available types of suspensory button fixation. Although no clinical studies to date have examined the difference between these techniques, multiple biomechanical investigations have directly compared these fixation methods. Petre et al evaluated 4 types of cortical suspensory fixation methods, including 2 fixed loop and 2 variable loop devices. The most crucial finding of this study was increased displacement as a result of device slippage that occurred with the variable loop design. This finding was supported by the findings of Barrow et al in a biomechanical study that suggested that lengthening of the variable loop design may lead to delayed graft healing and knee instability. However, Petre et al noted that variable loop devices allow for retensioning after tibial fixation, which can compensate for slippage. This is critical information for surgeons because they can correct for this.

**Table 1**
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Variable Loop</th>
<th>Fixed Loop</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age at surgery, mean, y</td>
<td>28.9</td>
<td>27.3</td>
<td>.42</td>
</tr>
<tr>
<td>Anterior cruciate ligament type</td>
<td>Tibialis anterior allograft, 67.4%</td>
<td>Tibialis anterior allograft, 31.9%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hamstring autograft, 32.6%</td>
<td>Hamstring autograft, 24.6%</td>
<td></td>
</tr>
<tr>
<td>Anterior cruciate ligament rerupture rate</td>
<td>4.7%</td>
<td>8.7%</td>
<td>.21</td>
</tr>
</tbody>
</table>

**Table 2**
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Variable Loop</th>
<th>Fixed Loop</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>KT-1000 value, mean, mm</td>
<td>0.38</td>
<td>0.92</td>
<td>.19</td>
</tr>
<tr>
<td>Patients with KT-1000&gt;3 mm</td>
<td>6.1%</td>
<td>12.5%</td>
<td>.20</td>
</tr>
</tbody>
</table>

aKT-1000 knee ligament arthrometer (MEDmetric, San Diego, California).

**Table 3**
<table>
<thead>
<tr>
<th>Outcome Score</th>
<th>Variable Loop</th>
<th>Fixed Loop</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preinjury Tegner</td>
<td>8.00</td>
<td>6.92</td>
<td>.09</td>
</tr>
<tr>
<td>Postinjury Tegner</td>
<td>6.21</td>
<td>6.46</td>
<td>.61</td>
</tr>
<tr>
<td>Lysholm</td>
<td>87.28</td>
<td>91.31</td>
<td>.37</td>
</tr>
<tr>
<td>SF-12 PCS</td>
<td>53.18</td>
<td>54.89</td>
<td>.33</td>
</tr>
<tr>
<td>SF-12 MCS</td>
<td>54.84</td>
<td>54.82</td>
<td>.99</td>
</tr>
</tbody>
</table>

Abbreviations: SF-12 MCS, 12-Item Short Form Health Survey mental component score; SF-12 PCS, 12-Item Short Form Health Survey physical component score.
intraoperatively and avoid potential effects on clinical outcomes. The current study did not find increased laxity, as measured with KT-1000 testing, or any functional difference between the variable and fixed groups. Retensioning the graft after tibial fixation is standard practice in the authors’ variable loop fixation technique.

A biomechanical study performed by Johnson et al\textsuperscript{15} found that, even after secondary tensioning, the variable loop system was characterized by increased slippage. The increased slippage seen in variable loop systems, although biomechanically shown, was not seen in the current study. An explanation for this is that the potential increased graft initially pulled into the bony tunnel with the variable loop may be nullified by slippage after cycling. Another possible explanation is that the force needed to cause variable loop slippage after tensioning actually may be supraphysiologic and therefore does not occur after ACL surgery. More generally, this discrepancy raises the question of whether biomechanical ACL models accurately replicate clinical scenarios.

The current results showed no statistically significant difference in KT-1000 measurements with fixed loop vs variable loop fixation methods. It was hypothesized that variable loop button fixation would provide more secure fixation and ultimately decreased laxity compared with fixed loop fixation. This initial hypothesis was based on the principles of ACL graft healing and incorporation along with the clinical finding that variable loop fixation methods allow surgeons to consistently draw a greater amount of graft into the femoral tunnel. Based on histologic studies that showed that ACL grafts incorporate with bony ingrowth through the fibrous graft-tunnel interface formed along the entire length of the tunnel,\textsuperscript{13,16} it would be expected that a larger tendon-bone interface would result in more collagen fibers to anchor the tendon to the bone, thus providing greater resistance to graft pullout and failure, especially during early healing.

The study hypothesis was also supported by Rodeo et al\textsuperscript{16} who showed that graft motion within the tunnel, which is greater with suspensory fixation, slowed graft incorporation and contributed to tunnel widening. These authors found that this motion is greatest at the intra-articular tunnel entrance and decreases along the tunnel because the graft is closer to the extra-articular fixation point. Variable loop fixation allows the graft to be consistently pulled closer to this fixation point, theoretically allowing for a larger area of more rapid incorporation. Rodeo et al\textsuperscript{16} also showed that bone ingrowth of the graft occurs more readily when there is less motion and closer apposition within the tunnel. Again, variable loop fixation allows more graft to be placed closer to the tunnel exits, where this closer apposition occurs, leading to more secure fixation.

The finding that there was no statistically significant difference in objective graft laxity as opposed to decreased laxity in the variable group, as hypothesized, may be a result of sliding or loosening that occurs with this type of fixation that could not be accounted for by retensioning of the graft after final tibial fixation, as discussed earlier. Another explanation could be that, with proper closed loop button fixation technique, a negligible difference occurs in the amount of graft within the tunnel. Whether the amount of graft in the tunnel after reconstruction with fixed or variable loop fixation differs at follow-up is a question that remains.

In addition to equivalent findings in objective graft laxity, no difference was found in patient-reported functional outcomes between the groups. Historically, ACL grafts associated with a KT-1000 measurement of 3 mm or greater have been characterized as clinically lax.\textsuperscript{17-19} In the current study, functional scores in patients with a KT-1000 measurement of 3 mm or greater did not differ significantly from those of the rest of the study group. This finding may be supported by the fact that rotational instability is more important in terms of functional and knee contact mechanics than anterior-posterior translation, as is evaluated with KT-1000 testing.\textsuperscript{20-23} Tunnel placement has a greater effect on the rotational stability of the reconstruction than does the method of fixation.\textsuperscript{24}

Although the current findings did not show a statistically significant difference in outcomes, both the rate of ACL rerupture and the rate of clinically lax grafts were approximately double in the fixed group compared with the variable group: 12.5% vs 6.1% for clinically lax grafts and 8.7% vs 4.7% for reruptures. The authors believe that the finding of improved values in the variable group for every objective graft measurement, including mean KT-1000 value, graft rerupture rate, and clinically lax graft rate, warrants further consideration. These findings may be explained, at least in part, by the principles of ACL graft healing and incorporation that were discussed earlier.

Limitations

This study had several strengths as well as limitations. In terms of strengths, to the authors’ knowledge, this is the only clinical study comparing clinical outcomes of ACL reconstruction with fixed and variable loop button techniques. Much of the current discussion of these techniques is based on biomechanical comparisons rather than clinical data, and this study may help to guide clinical practice. An additional strength is the fact that a single surgeon performed all of the procedures with the same technique. Further, all of the KT-1000 measurements were performed by blinded physical therapists, and all data were collected by independent coauthors.

Some of the limitations of this study are related to its retrospective design. Some variations occurred in the grafts that were used for the reconstructions. Although the specific graft types varied in the 2 surgi-
cial groups based on the time when they were performed (Table 1), the overall proportion of autografts vs allografts in each subset was similar (32.6% vs 30.3% autografts in the variable group vs the fixed group, respectively). This variation in graft selection reflects the primary surgeon’s temporal change in preference and is something that cannot be selected for in a retrospective surgical analysis. The similar breakdown of allograft vs autograft, along with the comparable mean patient age, allows meaningful comparisons to be drawn.

Any study that involves retrospectively contacting subjects is inherently at risk for bias. Potential subjects were contacted multiple times and given several options of response modes to minimize recall bias. In addition, all of the medical records were reviewed, and the vast majority of patients who did not participate did not have postoperative complications.

Finally, the sample size, as limited by surgical case number and response rate, is worth mentioning. Although the sample was fairly small, it was sufficiently powered to detect a 2-mm difference in KT-1000 measurement. This is crucial because this value is below the 3-mm threshold that is historically considered to define a clinically lax graft. As discussed previously, variable loop systems resulted in lower values for mean KT-1000 value, graft rerupture rate, and clinically lax graft rate than were found for fixed loop systems, but the difference was not statistically significant. The authors believe that these consistencies warrant more consideration. The study confirmed that variable loop button fixation is an acceptable means to achieve femoral graft fixation during ACL reconstruction, despite biomechanical studies that showed graft slippage with these devices.

REFERENCES


