Original article

Lack of stability at more than 12 months of follow-up after anterior cruciate ligament reconstruction using all-inside quadruple-stranded semitendinosus graft with adjustable cortical button fixation in both femoral and tibial sides

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\section*{ABSTRACT}

\textbf{Introduction:} The use of the semitendinosus tendon alone for anterior cruciate ligament reconstruction keeps the gracilis muscle intact and decreases anterior pain in comparison with the use of the patellar tendon. Recently, Lubowitz described a new all-inside technique with an ST4 tendon fixed with a cortical button in both femoral and tibial sides. We hypothesized that this type of graft with cortical button fixation provides well-controlled residual anterior tibial translation (<3 mm).

The aim of this study was to assess the results obtained with this technique in terms of laxity and IKDC score at more than 1 year of follow-up.

\textbf{Material and methods:} We performed a prospective single-center study to evaluate the results with this procedure with at least 1 year of follow-up. The primary endpoint was the objective IKDC score and side-to-side anterior tibial translation difference. The secondary endpoint was the subjective assessment using the subjective IKDC and Lysholm scores. Tunnel positioning was assessed using the Aglietti criteria.

\textbf{Results:} Thirty-five patients were included and reviewed with a mean follow-up of 19.7 months. Sixty-three percent of the patients were male and the mean age at the procedure was 28 years. The IKDC score was A or B in 43% of the patients and C or D in 57%; 54% of the patients had a residual side-to-side anterior tibial translation difference less than 3 mm and 29% presented significant pivot shift (grade C or D). Five patients underwent revision surgery, including one for rupture of the ACL reconstruction. The meniscal status did not influence postoperative laxity and the IKDC grade.

\textbf{Discussion:} Our hypothesis was not verified and the postoperative stability of the knee was insufficient. Postoperative side-to-side anterior tibial translation difference remained greater than 3 mm for 16 patients and the analysis seems to indicate that the distal cortical fixation of the graft with an adjusted loop is insufficient.

\textbf{Level of evidence:} Prospective study – Level IV.

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1. Introduction

Many anterior cruciate ligament (ACL) reconstruction techniques exist today. The patellar tendon and the STG (semitendinosus/gracilis) tendons are the most frequently used transplants. STG reconstructions can reduce anterior knee pain and limit extension deficits [1,2]. Recently, several authors have suggested using the semitendinosus tendon alone (four strands, or ST4) for single-bundle reconstructions. These short grafts reduce the loss in strength of the knee flexors [3,4].

For the fixation of these short grafts, many authors use distal cortical fixation for the femoral fixation with good clinical and biomechanical results [5–7], but the tibial fixation is most often provided by an interference screw. In 2011, Lubowitz et al. suggested an all-inside ACL reconstruction technique, using an ST4 graft associated with a distal cortical fixation at the femur and the tibia [8]. This attractive technique makes it possible to perform a retrograde tibial tunnel that limits bone substance loss and

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stabilizes the graft with an adjustable fixation system (TightRope™, Arthrex, Naples, FL, USA).

The objective of this study was to assess the results of this technique with a minimum 1-year postoperative follow-up period. The primary endpoint was residual laxity at a minimum follow-up of 12 months, evaluated using the IKDC score associated with side-to-side anterior tibial translation difference measured using the KT-1000™ (MedMetric, San Diego, CA, USA). The secondary endpoint was the subjective assessment using the IKDC subjective score and the Lysholm score. We hypothesized that this less invasive technique would provide postoperative residual laxity similar to that found in the literature despite distal tibial fixation of the graft.

2. Material and methods

2.1. Population

In this prospective single-center study conducted between April 2011 and October 2013 in the Reims University Hospital Orthopaedics Center (France), the inclusion criteria were age over 18 years, participation in a pivot sport (with or without contact), ACL tear confirmed by MRI, presence of side-to-side anterior tibial translation difference measured with the KT 1000™ (MedMetric) greater than 3 mm, and no history of knee surgery. Existence of a meniscus tear was not a factor of exclusion. ACL reconstructions were performed with an all-inside technique performed using the GraftLink All-Inside™ (Arthrex) ancillary instrumentation [8,9]. All patients presenting a collateral ligament lesion, a severe cartilage lesion, a partial ACL lesion, an associated fracture, or a contralateral ACL injury were excluded.

During the inclusion period, 208 ACL reconstructions were performed arthroscopically in our department.

Forty-four patients were initially included after having provided their agreement to participate in the study. Nine of them were lost to follow-up before 1 year. In this group of patients lost to follow-up, no complication was found at the last follow-up. Therefore, 35 patients (22 males and 13 females) underwent clinical and radiological review with a minimum follow-up of 12 months. The mean follow-up was 19.7 months (range, 12–39 months). The mean age at the time of surgery was 28 years (±7.8 years), and the mean body mass index was 24.4 kg/m² (±3.5 kg/m²). The mean time to surgery was 9.9 months (±17.4 months). Preoperatively, all the patients presented positive pivot shift: six (17%) subnormal pivot shift (grade B), 17 (49%) abnormal pivot shift (grade C), and 12 (34%) very abnormal pivot shift (grade D).

2.2. Operative technique

- The semitendinosus was first harvested. No complication was observed during this stage.
- The short graft was prepared according to the company’s guidelines: the length of the transplant adjusted to have four strands, with 1 min of pretension performed, providing one ST4 mounted with two TightRope™ implants (Arthrex) [10].
- The second phase was arthroscopic: evaluation of the ligament, meniscus, and chondral lesions. In case of meniscus tear, it was treated first: as far as possible the tear was repaired using anchors (Meniscal Cinch™, Arthrex); if not, a partial meniscectomy was performed: seven partial lateral meniscectomies, five partial medial meniscectomies, and four medial meniscal repairs were performed in 14 patients (two patients had a lesion in both menisci). The femoral tunnel was drilled via the anteromedial approach (differing from the out-in technique described by Lubowitz) with an alignment guide 5 mm away, at 11 o’clock for the right knees and 1 o’clock for the left knees, and then a blind tunnel was carried out. The tibial tunnel was performed using an alignment device adjusted to 55°, then a blind tunnel was carried out using the FlipCutter™ (Arthrex). The drilling diameters and depths were defined when the graft was prepared with the calibrator.
- In the last phase, the graft was introduced in the joint, with the femoral fixation first, then after ten cycles of flexion/extension, the tibial fixation was performed at 15° flexion, avoiding any tibial anterior drawer (Fig. 1).

No lateral tenodesis was performed.

After surgery, the knee was immobilized with a brace articulated at 0–90°, worn for 1 month until the first follow-up visit, and immediate weightbearing was authorized. Physical therapy was initiated on D1 postoperative with the same protocol for all patients.

2.3. Evaluation

The preoperative workup comprised X-rays, MRI, and comparative side-to-side anterior tibial translation difference using the KT-1000™ (MedMetric) as recommended by the manufacturer and performed by the same experienced operator.

Postoperatively, the patients were seen at M1 (1 month), M2, M3, M4, M7, and M12. The assessment at 12 months included X-rays, comparative side-to-side anterior tibial translation difference measured using the KT-1000™ (MedMetric), a questionnaire, and clinical examination to determine the objective IKDC (International Knee Documentation Committee) score. The subjective IKDC score and the Lysholm score [11] were completed by the patient during consultation. A Lysholm score between 84 and 100 points was considered good, between 65 and 83 points fair, and if less than 64 points poor [12].

Tunnel placement was evaluated on X-rays according to the Aglietti criteria [13] (Fig. 2).

2.4. Statistical analysis

The statistical analysis was performed by the Reims University Hospital’s Public Health Department. The descriptive analysis of the quantitative variables was based on the mean and standard deviation (SD), and for the qualitative variables percentages were used. The objective IKDC grade was compared for before and after the intervention (using the McNemar chi-square test, with the IKDC grade reduced to two categories: A/B and C/D), and the
before- and after-surgery subjective IKDC score (using the paired Student t-test) was calculated. Finally, the association between the qualitative and quantitative variables was studied using the Pearson correlation, Student, and chi-square or Fisher exact tests (depending on the conditions of application). All of the analyses were carried out using SAS 9.2 software (SAS Institute, Cary, NC, USA). The significance threshold was 0.05.

3. Results

3.1. Complications

The cortical buttons were perfectly applied to the tibial or femoral cortex in all cases except one patient for whom there was a 4-mm gap between the femoral button and the cortex. This patient’s case is described below.

Five patients (14%) underwent surgical revision:

- Two partial meniscectomies on medial meniscus lesions at 7 and 9 months after reconstruction, one of which was a repair failure.
- Two button removals due to invalidating pain when sports were resumed, one on the tibia, one on the femur (removed 10 and 12 months after reconstruction, respectively). The painful femoral button was intra-articular.
- One secondary medial meniscal repair associated with notch-plasty 18 months after reconstruction. This patient had residual laxity from a technical error (femoral button insufficiently close to the cortex) and required ACL revision.

3.2. Clinical evaluation

3.2.1. Objective IKDC grade and laxity

Before surgery, one patient was grade A/B (3%) and 34 patients grade C/D (97%). At a minimum 12 months after surgery, 15 patients were grade A or B (43%) and 20 patients grade C or D (57%) (Fig. 3). Objective IKDC subgroups are presented in Table 1. The mean postoperative residual side-to-side anterior tibial translation difference significantly improved (P < 0.05) but only 54.2% of the patients (19 patients) presented side-to-side anterior tibial translation difference less than 3 mm (Table 2). At more than 1 year, ten patients presented abnormal or very abnormal pivot shift (grade C or D).

Having undergone meniscal repair or partial meniscectomy did not significantly modify the postoperative IKDC grade and postoperative residual laxity.

Three cases of lack of extension less than 5° were observed, and a loss of flexion was noted in 11 cases (31.4%). Eight were IKDC grade B (flexion deficit between 6 and 15°) and three were IKDC grade C (flexion deficit between 16 and 25°).

3.2.2. Subjective evaluation

The mean postoperative IKDC and Lysholm scores (Table 3) improved significantly compared to the preoperative scores (P < 0.001). Partial meniscectomy did not significantly influence the postoperative subjective scores.

One patient (3%) presented a recurrent tear of the transplant 22 months postoperative during a soccer injury, clinically diagnosed and confirmed on MRI. He was then lost to follow-up.

### Table 1

<table>
<thead>
<tr>
<th>Postoperative anterior tibial translation side-to-side difference (KT-1000)</th>
<th>A normal</th>
<th>B subnormal</th>
<th>C abnormal</th>
<th>D very abnormal</th>
</tr>
</thead>
<tbody>
<tr>
<td>19</td>
<td>9</td>
<td>7</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>3</td>
<td>6</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>4</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>8</td>
<td>3</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>9</td>
<td>6</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

### Table 2

<table>
<thead>
<tr>
<th>Postoperative anterior tibial translation side-to-side difference as measured by the KT-1000 compared to healthy knee.</th>
<th>Preoperative</th>
<th>Postoperative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean side-to-side difference in mm (SD)</td>
<td>7 (±2.7)</td>
<td>2.8 (±2.4)</td>
</tr>
<tr>
<td>&lt;3 mm (IKDC A)</td>
<td>0</td>
<td>19 (54%)</td>
</tr>
<tr>
<td>Between 3 and 5 mm (IKDC B)</td>
<td>0</td>
<td>9 (26%)</td>
</tr>
<tr>
<td>Between 6 and 10 mm (IKDC C)</td>
<td>14 (40%)</td>
<td>7 (20%)</td>
</tr>
<tr>
<td>&gt;10 mm (IKDC D)</td>
<td>21 (60%)</td>
<td>0</td>
</tr>
</tbody>
</table>
Table 3
Pre- and postoperative subjective IKDC and Lysholm scores.

<table>
<thead>
<tr>
<th></th>
<th>Preoperative</th>
<th>Postoperative</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean IKDC score (SD)</td>
<td>42% (±21)</td>
<td>71.8% (±16.7)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Mean Lysholm score (SD)</td>
<td>44.3 (±25.3)</td>
<td>79.6 (±17.4)</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

Table 4
Radiological positioning of tunnels on a lateral view according to Aglietti criteria.

<table>
<thead>
<tr>
<th></th>
<th>Femur</th>
<th>Tibia</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 cases</td>
<td>1 cases</td>
</tr>
<tr>
<td>Lysholm good (%)</td>
<td>2 cases</td>
<td>6 cases</td>
</tr>
<tr>
<td>Lysholm fair (%)</td>
<td>4 cases</td>
<td>11 cases</td>
</tr>
<tr>
<td>Lysholm poor (%)</td>
<td>29 cases</td>
<td>83% cases</td>
</tr>
</tbody>
</table>

3.3. Radiological evaluation

Postoperative femoral and tibial tunnel placement was assessed radiologically according to the Aglietti criteria. All the femoral tunnels were positioned in the posterior part of the lateral femoral condyle (Table 4).

Those patients presenting loss of flexion between 6 and 15° (eight cases) had a tibial tunnel positioned at a mean 32.2° (±7.8°) posterior according to the Aglietti criteria; those with a loss of flexion between 16 and 25° (three cases) had a tibial tunnel positioned at a mean 29.3° (±6.1°) posterior according to the same criteria. This difference was not statistically significant.

4. Discussion

At a minimum 12 months follow-up, the results are disappointing with this surgical technique. Control of laxity was insufficient and morbidity was not reduced. This series showed reduced postoperative laxity, but only 54% of the patients presented residual side-to-side anterior tibial translation difference lower than the 3-mm threshold and 43% presented IKDC grade A or B at the last follow-up. Our hypothesis was not confirmed.

4.1. Laxity

Many studies evaluating residual laxity after ACL reconstruction have been published. For ST4 reconstruction, residual side-to-side anterior tibial translation difference usually remains under 3 mm [14–20] (Table 5). In the present series, 46% of our patients retained significant residual side-to-side anterior tibial translation difference greater than 3 mm (grade IKDC B or C). Several factors can explain these differences.

Cortical button fixation associated with adjustable loops at the tibia and the femur (TightRope™, Arthrex) corresponds to the technique developed by Lubowitz. Biomechanical studies [5,21] have shown significantly greater resistance to avulsion for the fixed-length loop Endobutton CL™ (Smith and Nephew, London, UK) compared to the TightRope™. The total displacement (elongation) after 1000 cycles is significantly higher in the two studies for the TightRope™ compared to the Endobutton CL™. These results therefore suggest that the fixation system that was used in the present study was inferior in terms of solidity compared to fixed-length loop distal cortical fixations. Walsh et al. found similar results in a biomechanical study comparing a tibial interference screw with a distal cortical fixation [22].

Clinical and biomechanical studies have already established that the distal femoral cortical button fixation was reliable [5,6]. This type of fixation does not seem to be the cause of our disappointing results.

We found no clinical studies in the literature reporting the results of ST4 reconstruction using adjustable cortical button fixation at the femur and the tibia. However, a recent biomechanical study conducted by Mayr et al. in 2015 [23] compared elongation of an ST4 transplant fixed to the femur with a TightRope RT™ and fixed to the tibia with a TightRope RT™ or an interference screw (BioComposite, Arthrex). They found 6.03 mm (±0.61 mm) total transplant lengthening after 1000 cycles for the distal tibial fixation and 3.33 mm (±0.83 mm) for the tibial interference screw fixation (P < 0.001). The authors therefore recommend using an interference screw for tibial fixation after ST4 reconstruction.

Poor positioning of the tunnels can influence laxity [13,24,25]. Excessively anterior femoral tunnel positioning can run the risk of poor control of the anterior drawer and therefore increase residual laxity, whereas the positioning of the tibial tunnel does not seem to play a role in anteroposterior laxity [13]. According to the Aglietti criteria, all the femoral tunnels in the present study were positioned in the posterior half of the lateral femoral condyle and therefore were in optimal position.

4.2. Objective results

The objective IKDC grade was significantly improved in this study. However, this improvement was less than what was expected based on medium- and long-terms studies of ST4 reconstruction (Table 5).

Table 5
Review of the literature of the main studies on ST4 ligament reconstruction.

<table>
<thead>
<tr>
<th>Study</th>
<th>Follow-up</th>
<th>Transplant</th>
<th>Fixation</th>
<th>Objective IKDC</th>
<th>Residual instability</th>
<th>Meniscus lesions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Femoral</td>
<td>Tibial</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Buchner et al. [14]</td>
<td>≥6 years</td>
<td>ST4</td>
<td>Endobutton®</td>
<td>Suture disc (Smith &amp; Nephew)</td>
<td>85% A or B</td>
<td>&lt;3 mm: 75%</td>
</tr>
<tr>
<td>Streich et al. [20]</td>
<td>10 years</td>
<td>ST4</td>
<td>Endobutton®</td>
<td>Suture disc (Aesculap)</td>
<td>N/A</td>
<td>&lt;3 mm: 78%</td>
</tr>
<tr>
<td>Cooley et al. [15]</td>
<td>≥5 years</td>
<td>ST4</td>
<td>N/A</td>
<td>N/A</td>
<td>85% A or B</td>
<td>&lt;2 mm: 100%</td>
</tr>
<tr>
<td>Eriksson et al. [16]</td>
<td>≥2 years</td>
<td>ST4</td>
<td>Endobutton®</td>
<td>Interference screw</td>
<td>41% A or B</td>
<td>&lt;3 mm: 46%</td>
</tr>
<tr>
<td>Liden et al. [18]</td>
<td>7 years</td>
<td>ST4</td>
<td>Interference screw</td>
<td>Interference screw</td>
<td>50% A or B</td>
<td>Mean ≥ 2.6 mm</td>
</tr>
<tr>
<td>Kyung et al. [17]</td>
<td>≥2 years</td>
<td>ST4</td>
<td>Endobutton®</td>
<td>Post-fixation interference screw</td>
<td>N/A</td>
<td>Mean ≥ 2.3 mm</td>
</tr>
<tr>
<td>Mohtadi et al. [19]</td>
<td>1 year</td>
<td>ST4</td>
<td>Endobutton®</td>
<td>Interference screw</td>
<td>83% A or B</td>
<td>Mean ≥ 2.8 mm</td>
</tr>
<tr>
<td>Our series</td>
<td>&gt;1 year</td>
<td>ST4</td>
<td>TightRope RT™</td>
<td>TightRope RT™</td>
<td>43% A or B</td>
<td>&lt;3 mm: 92%</td>
</tr>
</tbody>
</table>
In our nonexhaustive review of the literature, the opinions on the inclusion of meniscus tears are highly heterogenous. In this clinical series, the only variable significantly correlated with the objective postoperative IKDC grade was the presence of an intraoperative meniscus tear. We noted 16 intraoperative meniscus lesions (45.7%), four of which were repaired. This correlation was also found in the series reported by Barenien and Eriksson [16,26] and partially explains our results found on this score.

Joint range of motion was reduced compared to the healthy side. These results are comparable to others reported in the literature [4,15,16,26,27]. We noted few cases of lack of extension in this series, but there was a flexion deficit in 11 patients (31%). This may be explained by the posterior positioning of the tibial tunnel (>25% according to the Aglietti criteria).

4.3. Subjective results

Although the subjective improvement was significant, these scores were lower than those found in the literature [14,16–20,26]. This difference is in agreement with the results observed on the objective IKDC score in the same series and should be considered in relation to the short follow-up period. Barenien and Eriksson [16,26] found improvement in these scores between the 2nd and 8th year after surgery, as is seen in other studies such as the prospective study reported by Reddy et al. [28]. In our series, there was no significant relation between the subjective scores and the IKDC grade.

4.4. Complications

Anterior pain was less frequent than in the series investigating patellar tendon techniques on higher numbers of patients [29,30]. On the other hand, pathologies at the harvest site were comparable to Pinczevski et al.’s series [2]. In the studies comparing ligament reconstructions using the patellar tendon with those using the STG or the ST4, no significant difference was found over the long term for anterior pain [16,18,29].

The number of surgical revisions for discomfort caused by the material or for meniscus tears was equivalent to the series of Streich et al. [20] but higher than other studies with greater numbers of patients and longer follow-up [14,16,18,26]. These revisions for meniscus tears can probably be explained by the lack of stability in our ACL reconstructions.

4.5. Limitations

We acknowledge several limitations in this study. First of all, the limited number of patients did not allow us to obtain significant values for subgroup analysis. In addition, many patients were lost to follow-up despite the study’s prospective design. The population was heterogenous in terms of time to surgery and meniscus tears. We then began the study rapidly after introducing this new surgical technique in our department.

5. Conclusion

The results of our series are disappointing because residual laxity was excessive, leading to a lower IKDC grade than expected. The short graft used with other means of fixation does not seem to give satisfactory results. The adjustable loop distal tibial cortical fixation does not provide all the guarantees required for stable and optimal fixation of the ST4 transplant.

Given the disappointing results obtained, we no longer use this type of fixation.

Disclosure of interest
The authors declare that they have no competing interest.

References


