Original article

Revision single-bundle anterior cruciate ligament reconstruction with over-the-top route procedure

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ABSTRACT

Purpose: In revision anterior cruciate ligament reconstruction (ACLR), the single-stage technique and the over-the-top route (OTTR) procedure were usually selected for cases where the bone tunnel cannot be created at an anatomical position due to tunnel enlargement and overlap with the mal-positioned tunnel of primary reconstruction. The purpose of this study was to evaluate the clinical results of revision single-bundle ACLR reconstruction using OTTR procedure and to compare the clinical results of OTTR procedure with those of anatomical single-bundle revision reconstruction (SBR).

Hypothesis: The results of OTTR procedure are equivalent to that of SBR.

Methods: Seventy-six revision ACLR reconstruction cases from April 2002 to December 2012 were involved in our study. We focused on 21 knees which underwent surgery with SBR and 22 knees with OTTR using hamstring tendon. The clinical results were evaluated by means of the Lysholm score and the knee stability was assessed by the Lachman test, pivot-shift test and side-to-side difference by KT-2000 pre-operatively and after 1 year post-operatively. AP translation and rotational laxity using a navigation system were evaluated before and after revision ACL reconstruction under anesthesia in 8 cases of OTTR and in 6 cases of SBR.

Results: There was no statistically significant difference between the OTTR and SBR regarding Lysholm score, Lachman test, pivot-shift test, ATT by KT-2000, and AP translation and rotational laxity with a navigation system.

Conclusions: The clinical results of OTTR are almost equivalent to those of SBR. For the cases in which it is impossible to create the femoral tunnel in an anatomical position, OTTR is a valuable revision ACL reconstruction method.

Level of evidence: Case-control study. Level III.

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1. Introduction

The revision anterior cruciate ligament reconstruction (ACLR) procedures are more complex than those of primary reconstruction, because the pre-operation status differs from case to case, with the most demanding cases being those where the femoral tunnel cannot be created due to bone tunnel enlargement. As a general rule, second-stage revision surgery using bone grafting has been performed for such cases. However, they require a long therapeutic period which may cause mental distress to a patient and jeopardize an athlete’s career. Therefore, the single-stage technique for revision ACLR has been recommended and the over-the-top route (OTTR) procedure has been selected for cases where the bone tunnel could not be created in an anatomical position due to tunnel enlargement and overlap with the mal-positioned tunnel of primary reconstruction. OTTR procedure had been regarded as the last ACLR revision option and salvage procedure for skeletally immature patients [1,2]. Previous clinical reports showed that OTTR procedure restore antero-posterior (AP) stability, but it is unknown whether rotational stability is restored or not [3,4]. Recent studies have reported that OTTR restores intact knee kinematics, and that the antero-posterior stability and rotation stability of OTTR are comparable to that of anatomical single-bundle reconstruction [5,6]. However, no report has evaluated the clinical results relating to knee stability of OTTR procedure in revision ACLR.

The purpose of this study is to evaluate the clinical results of revision single-bundle ACLR reconstruction using OTTR procedure and to compare the clinical results of OTTR procedure with those...
of single-bundle revision reconstruction (SBR). Our hypothesis is that the results of OTTR procedure are equivalent to that of SBR.

2. Material and methods

Seventy-six revision ACL reconstruction knees from April 2002 to December 2012 were involved in our study. Twenty-one knees which underwent surgery with SBR and 22 knees with OTTR procedure using hamstring tendon retrospectively. There was no statistically significant difference between the OTTR group and SBR group regarding gender, age, interval from primary ACLR to reconstructed ACL failure and interval reconstructed ACL failure to revision surgery (Table 1). At the time of revision ACLR, meniscal and chondral injury was observed in 7 patients of SBR and 8 patients of OTTR procedure. There was no statistically significant difference in the presence of meniscus and cartilage lesions.

All surgery were performed and directed by senior author (M.O), using autologous quadrupled semitendinous tendon. The ipsilateral semitendinosus tendon was harvested if it had not been used for primary reconstruction, but the contralateral semitendinosus tendon was harvested if it had been used for primary ACL reconstruction. In SBR, femoral graft fixation was achieved with EndoButton-CL (Smith&Nephew, Andover, Massachusetts) (Fig. 1). The distal ends of the graft were sutured with Endobutton tape (Smith&Nephew) and tibial fixation was achieved with two staples with the tension of 50 N. In OTTR procedure group (Figs. 2 and 3), the both ends (proximal and distal) were sutured with Endobutton tape. A 4-cm longitudinal skin incision was made proximal to the lateral femoral condyle. After incising the fascia lata, the vastus lateralis was reflected upwards. The periosteal was divided longitudinally. OTTR was made with curved Kelly’s forceps, inserted through the medial infra-patellar portal into the intercondylar space. The tip of the forceps was passed between ACL remnant and PCL to break the posterolateral capsule. After breaking the joint capsule, the tip of the forceps emerged at the lateral aspect of the femur, and the graft was passed through the same way. Finally, the graft was fixed to the distal femur with two staple and then tibial fixation was achieved with two staples with the tension of 50 N (Fig. 4).

Post-operative rehabilitation followed the same program as that of primary ACLR. Active quadriceps exercises were carried out as soon as possible. The knee was immobilized at 30° flexion for two days. Range of motion exercise was encouraged using continuous passive motion. The extension was limited at –30 degrees in a brace for three months to prevent the loosening of ACL graft. Partial weight-bearing was allowed at 10 days, full weight-bearing at 3 weeks and jogging at 4 months after surgery. Return to sports activity was permitted at 12 months after surgery.

The clinical results were evaluated by means of the Lysholm score pre-operatively and at 1 year post-operatively. The post-operative stability was assessed by the Lachman test, pivot-shift test and side-to-side difference of anterior-posterior translation of the tibia (ATT), as measured by the knee arthrometer (KT-2000, Medtronic) at 30 lbs pre-operatively and at 1 year post-operatively. The Lachman test and the pivot-shift test were simply classified as positive or negative.

AP translation and rotational laxity using a navigation system (Orthopilot ACL reconstruction V 2.0, B. Braun Aesculap, Tuttlingen, Germany) were evaluated before and after revision ACL reconstruction under anesthesia in 8 cases of OTTR group and in 6 cases of SBR group. ATT was measured under the anterior tibial loads of 100 N, and then the total range of tibial rotation (TTR) was measured under the rotational torque of 1.5 Nm using our original device with the knee at 30° of flexion [7,8].

3. Statistical analysis

The Chi² test was used to evaluate gender, the Lachman test and pivot-shift test. The Mann-Whitney U test was used to evaluate age, the Lysholm score, the interval from primary ACLR to reconstructed ACL failure, the interval from reconstructed ACL failure to revision surgery, the side-to-side difference of ATT was calculated by the knee arthrometer, and ATT and TTR was evaluated using a navigation system.

A P value of less than 0.05 was considered to indicate a statistically significant difference.

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![Fig. 1. Single-bundle revision reconstruction case. The primary femoral bone tunnel is in an anatomical position and not enlarged. a: arthroscopic view; b: 3D-CT.](image)

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<table>
<thead>
<tr>
<th>Table 1</th>
<th>Gender, age, interval from primary ACLR to ACL failure and interval from reconstructed ACL failure to revision surgery in both groups.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OTTR</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
</tr>
<tr>
<td>M: 10 F: 12</td>
<td>M: 7 F: 14</td>
</tr>
<tr>
<td>Age</td>
<td></td>
</tr>
<tr>
<td>32.3 (16–62)</td>
<td>30.9 (5–20)</td>
</tr>
<tr>
<td>Interval from primary</td>
<td></td>
</tr>
<tr>
<td>7.9 y</td>
<td>10.2 y</td>
</tr>
<tr>
<td>ACLR to ACL failure</td>
<td></td>
</tr>
<tr>
<td>(5m–25 y)</td>
<td>(5m–20 y)</td>
</tr>
<tr>
<td>Interval from reconstructed</td>
<td></td>
</tr>
<tr>
<td>2.8 y</td>
<td>2.9 y</td>
</tr>
<tr>
<td>ACL failure to revision surgery</td>
<td></td>
</tr>
<tr>
<td>(2m–15 y)</td>
<td>(2m–17 y)</td>
</tr>
</tbody>
</table>

Fig. 2. Over-the-top route revision reconstruction case. a: the primary femoral bone tunnel (dotted line) is enlarged and cannot be used; b: the posterior wall of the lateral femoral condyle (solid line); c: 3D-CT (solid line: anatomical position).

Fig. 3. Over-the-top route revision reconstruction case. The primary bone tunnel is enlarged and overlaps with the anatomical footprint. a: 3D-CT (solid line: anatomical position); b: the primary femoral tunnel (dotted line) and the ACL anatomical position (solid line); c, d: the graft was passed via OTTR.
4. Results

The results are shown in Tables 2 and 3. There were no statistically significant difference between OTTR and SBR group in the Lysholm score ($P=0.73$), Lachman ($P=0.51$), pivot-shift test ($P=0.49$), AP translation by the post-operative knee arthrometer ($P=0.20$), and the ATT ($P=0.48$) and TTR ($P=0.43$) using a navigation system.

![Fig. 4. 3D-CT of over-the-top route revision reconstruction case (arrow: staple).](image)

Table 2

<table>
<thead>
<tr>
<th>Clinical results</th>
<th>OTTR</th>
<th>SBR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-op</td>
<td>1 year</td>
</tr>
<tr>
<td>Lysholm score</td>
<td>62.8</td>
<td>93.0*</td>
</tr>
<tr>
<td>Lachman test (positive case/total)</td>
<td>22/22</td>
<td>1/22*</td>
</tr>
<tr>
<td>Pivot-shift test</td>
<td>22/22</td>
<td>1/22*</td>
</tr>
<tr>
<td>Side-to-side difference of ATT by the knee arthrometer at 30 lbs (mm)</td>
<td>4.5 ± 4.2</td>
<td>1.8 ± 1.7*</td>
</tr>
</tbody>
</table>

There is no statistically significant difference between revision OTTR and SBR in clinical results. OTTR: over-the-top route; SBR: single-bundle revision; ATT: anterior tibial translation. *P: 0.05: comparison between pre-op and 1 year.

Table 3

<table>
<thead>
<tr>
<th>Intraoperative stability</th>
<th>OTTR</th>
<th>SBR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before</td>
<td>After</td>
</tr>
<tr>
<td>ATT (mm)</td>
<td>9.6 ± 1.6</td>
<td>2.5 ± 0.9*</td>
</tr>
<tr>
<td>TTR (°)</td>
<td>10.7 ± 3.9</td>
<td>6.3 ± 3.2*</td>
</tr>
</tbody>
</table>

There is no statistically significant difference between revision OTTR and SBR in intraoperative stability. OTTR: over-the-top route; SBR: single-bundle reconstruction; ATT: anterior tibial translation; TTR: total range of tibial rotation. *P: 0.05: comparison between before and after.

5. Discussion

MacIntosh reported the procedure of OTTR for the first time in the 1970s [9,10], and since then various modified methods have been introduced [11,12]. At the time, it was thought that the OTTR procedure that was close to the isometric position was a useful option, because it was proposed that the isometric point was suitable for the femoral tunnel and that the OTTR procedure was easier than the tunnel technique [13,4]. In early reports in the 1990s, Redford et al. were already comparing the static laxity at 20 degrees and 90 degrees with the biomechanics of single-bundle OTT and isometric femoral tunnel techniques. They found that the OTTR procedure gave better antero-posterior stability and functioned like an intact ACL at 20 degrees of knee flexion [14], Jonsson et al. also found that OTTR procedure gave an excellent Lysholm score result, although AP laxity tended to increase up to 24 months, returning to its pre-operative condition [15]. However, a wealth of ACL research has resulted in improvements to anatomical ACLR. The femoral tunnel has been moved to a lower position (anatomical position) from the isometric point [16], and some publications have proven that anatomical reconstruction restores the AP and rotational stability closer to intact knee kinematics than is the case with isometric reconstruction [17–21]. Therefore, OTTR procedure is only used as a salvage open physis option for limited cases to avoid drilling in the lateral femoral condyle due to significant bone loss or due to the skeletally immaturity of an individual [1,2].

Since the early 2000s, knee surgeons have focused on the concept of partial ACL rupture, emphasizing the importance of
preserving the remnant [22–25]. As mechanoreceptors and blood flow remain in the ACL remnant, preserving the remnant could improve the proprioceptive function and promote remodeling of the substitute [26,27]. Using the KT-2000 knee arthrometer, Adachi et al. compared the knee stability achieved through remnant preserving augmentation via OTTR with the stability achieved through anatomical SBR. They reported that the AP stability of OTTR procedure is superior to that of SBR.

However, no report evaluated the kinematics after OTTR procedure, such as the difference between AP and rotational stability, although good clinical results are obtained in immature patients and augmentation cases. Asai compared and analyzed the dynamic rotational knee instability between anatomical SBR and OTTR procedure using the pivot-shift test and triaxial accelerometer, respectively. The results of OTTR procedure are comparable to those obtained from anatomical SBR [6]. Lertwanich et al. compared the AP (89–N anterior tibial load) and rotational (a combined 7–Nm valgus and 5–Nm internal tibial rotation torque) stability at 0, 15, 30, 60 and 90° knee flexion between OTTR procedure and the anatomical transphyseal technique [5]. They conclude that OTTR procedure restores almost intact knee kinematics, although the rotational stability of OTTR procedure at 30° is inferior to that obtained from the transphyseal technique.

In our current study, ATT and TTR were evaluated by a navigation system, showing no significant differences between SBR and OTTR procedure. The virtual result at time zero testing is identical to previous studies. In addition, both SBR and OTTR procedure show no significant differences in the Lysholm score, Lachman test, pivot-shift test and ATT using the knee arthrometer at 1 year follow-up although the rotational stability was not evaluated objectively at this follow-up. The OTTR procedure is thus safe, relatively easy to perform and provides good results, allowing surgeons to make the right choice when faced with a difficult clinical situation such as bone enlargement cases in revision anterior cruciate ligament reconstruction.

There are some limitations in our study. The first limitation is the small number of patients for evaluation of navigation system although this study shows no statistically significant difference between two groups. The second limitation is the short follow-up period. A longer follow-up such as 2 years is ideal to evaluate the clinical results of revision ACLR because there is a possibility that the clinical results have been worsening from year to year.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

References


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