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Combined over-the-top reconstruction with posterolateral bundle remnant re-tensioning in pediatric anterior cruciate ligament reconstruction: A technical note

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ABSTRACT

Epiphyseal injury, particular on femoral side, is a major concern in pediatric anterior cruciate ligament (ACL) reconstruction. Therefore, the over-the-top route (OTTR) method has frequently been selected in pediatric ACL reconstruction, with good clinical results reported. However, a cadaver study reported the inferior rotational stability of the OTTR method to that of anatomical single bundle reconstruction. In recent years, a new method of reconstruction, which involves the remnant being detached, re-tensioned, and re-attached, achieved good short-term results. We developed a surgical method to restore the remnant to the posterolateral (PL) bundle footprint and obtain rotational stability in patients, thereby preserving the remnant. We hypothesized that repairing the residual remnant to the PL bundle footprint in pediatric ACL reconstruction could achieve rotational stability. This report offers the surgical techniques for PL bundle tensioning repair using remnants in the pediatric ACL OTTR procedure.

1. Introduction

Epiphyseal injury, especially on the femoral side, is a potential complication in pediatric anterior cruciate ligament (ACL) reconstruction.[1,2] Several studies reported growth disturbance with the transphyseal method and overgrowth with the epiphyseal method,[3–5] thus we have performed pediatric ACL reconstruction using the over-the-top route (OTTR) method, which demonstrated good clinical results.[6] However, a cadaver study has reported the inferior rotational stability of the OTTR method to that of anatomical single-bundle reconstruction.[7]

The ACL remnant exhibited a biomechanical strength that stabilizes the anterior translation and rotation and preserves mechanoreceptors and vascularity.[8–10] Remnant-preserving ACL reconstruction has provided good clinical results in terms of revascularization, proprioceptive function, graft healing, and biomechanical properties.[11–13] In recent years, a new method of reconstruction, which involves the remnant being detached and re-attached with tension, achieved good short-term results.[14–16]

We developed a remnant preservation surgical technique that combines an OTTR with reattachment of the remnant to the posterolateral (PL) bundle footprint to obtain rotational stability in patients. We hypothesized that repairing the residual remnant to the PL bundle footprint in pediatric ACL reconstruction could achieve rotational stability.

This report offers a surgical technique for PL bundle tensioning repair, using remnants in the pediatric ACL OTTR procedure.

2. Materials and methods

2.1. Surgical indication

The indication for this remnant-tensioning technique included patients with ACL injury before epiphyseal closure and enough remnant to allow the No.0 FiberWire® (Arthrex Inc, FL, USA) application to the remnant and PL bundle repair. Physeal closure was evaluated by fat saturation T2-weighted magnetic resonance imaging (MRI); according to the criteria reported by Sasaki et al.[17] The contraindication included patients with insufficient remnants that could not allow No.0

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FiberWire® threading and PL bundle repair.

2.2. Surgical technique (Fig. 1)

A 4 cm longitudinal incision is created on the proximal medial side of the tibia. The semitendinosus tendon is harvested and folded in quadruplicate to construct the graft. An artificial ligament (TAKUMI LIGAFIT: Aimedic MMT, Tokyo, Japan) is sutured to both ends (Fig. 1a).

The inside of the knee joint is checked under arthroscopy. Appropriate treatment is administered if any meniscus or cartilage damage is observed. After confirming the remnant (Fig. 1b), two loops of No. 0 FiberWire® are passed through the medial portal (Fig. 1c). The remnant is detached from the surrounding tissue while applying tension to the sutured threads. The femoral footprint is dissected, and the soft tissue of the lateral femoral condyle is removed.

A 5-cm skin incision is created on the distal lateral femur. The iliotibial ligament is incised in a fibrous direction, the muscle belly of the vastus lateralis muscle is retracted anteriorly, and the joint capsule posterior to the lateral femoral condyle is released to allow for graft passage. The bone on the posterolateral aspect of the lateral femoral condyle was refreshed with shaver and sharp curette before passing the grafted tendon to the femoral side to enhance the healing of the graft in adult cases. However, bone curettage is dangerous in pediatric cases because the epiphyseal line of the lateral femoral condyle passes very close to the route of the grafted tendon. Therefore, only arthroscopically seen synovial tissue was removed.

An outside-in guide (Acufex, Smith & Nephew, Andover, MA, USA) under fluoroscopy was used to insert a 2.4-mm Kirschner wire (K-wire) into the center of the femoral PL footprint (Fig. 1d,e), and a thread is passed into the joint to guide the FiberWire® over the remnant using a suture retriever (Smith & Nephew) (Fig. 1f).

A tibial bone tunnel is created as anterior as possible to the ACL footprint and posterior to Pearson's knob. Fluoroscopy was used to minimize physeal injury and a 2.4-mm K-wire was inserted, followed by a 4.0-mm retrograde drill, to create a bone tunnel that matches the grafted tendon diameter. The K-wire should be inserted as perpendicular to the epiphyseal line as possible to minimize the extent of physeal injury. Additionally, a slit is created in the remnant with a scalpel slightly medial to the center of the bone tunnel, and only the surface of the attachment site is cauterized to minimize remnant damage.

The remnant was first guided into the hole created in the PL and fixed with manual max onto the endobutton (Smith & Nephew) at 30°knee flexion (Fig. 1g). The grafted tendon was then guided from the femoral side to the tibial side, and the tibial side is fixed with two staples (Fig. 1h). After checking the length pattern, the femoral side is fixed with two staples, applying 50 N of tension at 30° flexion.[18,19]

Table 1 shows advantages and disadvantages of the remnant-tensioning technique.

2.3. Postoperative management

The knee was immobilized at 20° flexion for three days postoperatively. Active and passive motion exercise was encouraged. Partial weight-bearing was allowed at one week, full-weight bearing at three weeks and jogging at four months postoperatively. Patients could return to sports activities at 10 months postoperatively.

Computed tomography was taken three days postoperatively to ensure the creation of a bone tunnel at the PL bundle footprint and the maintenance of adequate spacing between the bone tunnel and the physis (Fig. 2). MRI was taken one year postoperatively to ensure that the tensioning remnant was observed, with no early physeal closure (Fig. 3). The clinical outcomes one year postoperatively are evaluated with the International Knee Documentation Committee (IKDC) score, Total Knee Injury and Osteoarthritis Outcome Score, Lachman test, and pivot-shift test.

3. Discussion

The clinical relevance and benefits included the following: 1. The risk of growth disturbance and overgrowth can be minimized by keeping as much distance from the physis as possible, 2. Graft revascularization and improvement of proprioceptive function can be expected,[10,11,15] 3. The minimally invasive technique offers the chance of rotational stability without requiring a new graft.

We reported comparable results with anatomical single-bundle reconstruction when we performed pediatric ACL reconstruction using the OTTR technique to avoid growth disturbance due to phyeal injury.[6] Most other reports have concerned the OTTR performed together with lateral extra-articular tenodesis, which provides good stability in

Table 1
Advantages and disadvantages of remnant-tensioning technique.

Advantages	Disadvantages
Minimal risk of epiphysis injury in comparison with anatomical bone tunnel method	Dependent on volume of remnant
Reconstruction of the posterolateral bundle is expected to improve rotational stability	Fluoroscopy is required
No need to harvest new tissue	No evidence (there is no previous report)
Can be performed at any age	

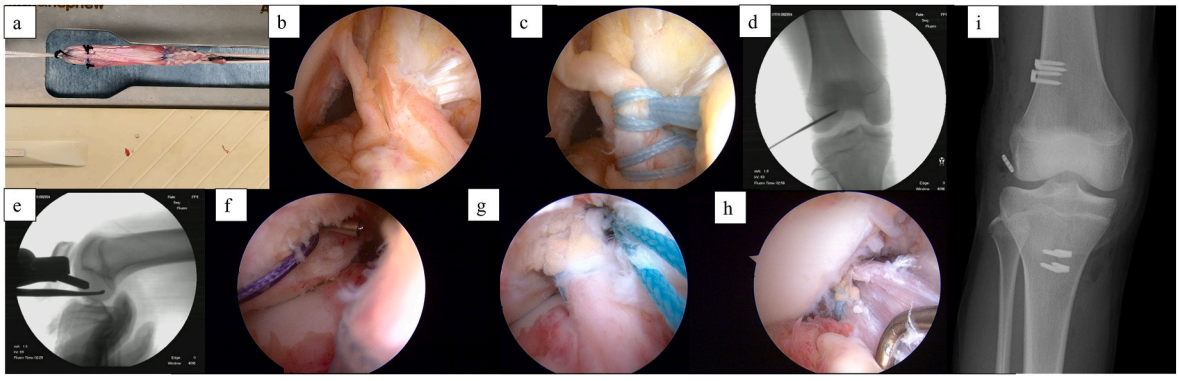

Fig. 1. Procedure of remnant-tensioning technique for posterolateral bundle with over-the-top route procedure a. Quadrupled semitendinosus tendon strands autograft. An artificial ligament is sutured to both ends b. Anterior cruciate ligament (ACL) remnant. c. Two loops of No. 0 FiberWire® are passed into the ACL remnant. d, e. A 2.4-mm Kirchner wire is inserted into the posterolateral (PL) footprint using an outside-in guide under fluoroscopy. f. A thread is passed into the joint to guide the FiberWire® using a suture retriever. g. The remnant is guided into the hole created in the PL and fixed with manual max onto the endobutton at 30°knee flexion. h. The grafted tendon is guided from the femoral side to the tibial side i: Postoperative frontal radiograph.

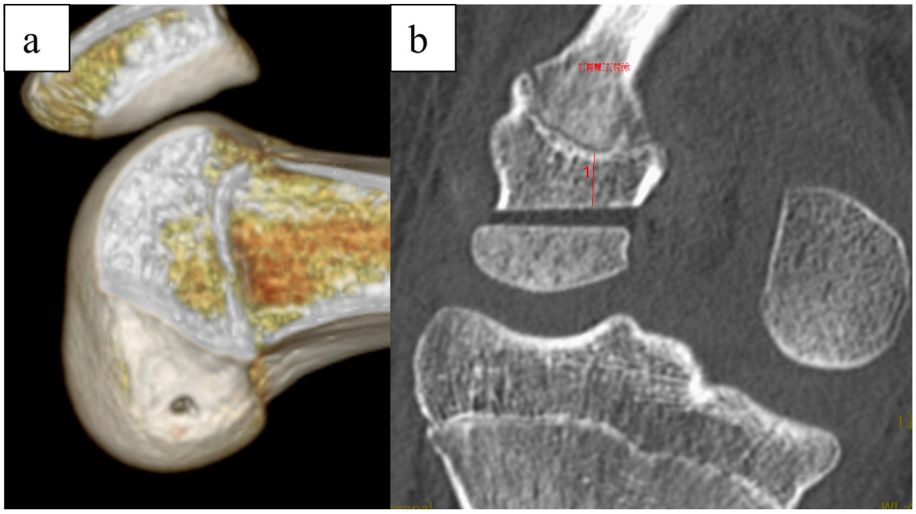

Fig. 2. Computed tomography at three days postoperatively (A 14-year-old girl). a: Three-dimensional computed tomography: A bone tunnel could be created at the posterolateral bundle footprint. b: Adequate spacing was maintained between the bone tunnel and the physis with a distance of 7.8 mm.

Fig. 3. Magnetic resonance imaging at one year postoperatively (A 14-year-old girl) The tensioning remnant was observed clearly with no early physeal closure was not observed on magnetic resonance imaging at one year postoperatively. (arrow: tensioning remnant; arrowhead: grafted tendon).

patients with skeletal immaturity.[20,21] Hence, the addition of lateral extra-articular tenodesis enhances rotational stability.[22] However, the OTTR procedure with the addition of lateral extra-articular tenodesis is problematic, because of its surgical invasiveness. In recent years, increased rates of treatment and earlier referral to specialists caused a greater awareness of ACL injuries. Hence, the remnant is frequently intact during surgery. Therefore, we hypothesized that repairing the remnant on the PL side might provide mechanical rotational stability.

Remnant preservation ACL reconstruction is reported to be better from the viewpoint of revascularization, proprioceptive function, graft healing, and biomechanical properties.[8–13] Better results have been reported than after remnant resection reconstruction. In recent years, a new method of reconstruction, which temporarily detaches the remnant and applies tension to the remnant has been reported.[14–16] Noh et al. revealed that the remnant-preserving and re-tensioning techniques provide satisfying short-term clinical results (Lachman test, pivot-shift test and knee clinical function score) and good synovial coverage on second-look arthroscopy.[14] Kim et al. demonstrated that the remnant-tensioning single bundle ACL reconstruction exhibits an outcome comparable to double bundle ACL reconstruction in terms of knee stability, clinical scores and second-look arthroscopic findings. Moreover, remnant-tensioning ACL reconstruction demonstrated better graft vascularity one year postoperatively than double bundle ACL reconstruction using dynamic-contrast-enhanced MRI.[15] Suh et al. revealed no occurrence of cyclops lesion in ACL reconstruction with remnant-tensioning, which is a concern with remnant-preserving reconstruction. The IKDC score was significantly better than that of the remnant resection ACL reconstruction.[16]

Our technique required a <2.4-mm bone tunnel to be created when tensioning the remnant, and the risk of growth disturbance and overgrowth that usually occurs with bone tunnel reconstruction can be minimized by keeping it as far away from the physis as possible. The tensioning remnant on the PL footprint stabilizes the rotation, which is also expected to improve graft vascularity to the grafted tendon and proprioceptive function by the techniques of remnant preserving and re-tensioning. The limitation of this study is its novelty with no reported evidence of clinically relevant benefits.

4. Conclusions

Our technique decreases the risk of physeal injury and provides good clinical results in pediatric ACL reconstruction.

Ethical approval

All data were collected and analyzed retrospectively from an Institutional-Review-Board-approved database, and the study was carried out according to the principles of the Declaration of Helsinki.

Informed consent

We obtained informed consent from all patients.

Disclosure statement

The authors declare that they have no conflict of interest.

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Contribution of authors

Goki Kamei: Collection and assembly of data, Data analysis and interpretation, Manuscript writing, Atsuo Nakamae: Data analysis and interpretation,
Kyohei Nakata: Collection and assembly of data,
Akinori Nekomoto: Collection and assembly of data,
Shunya Tsuji: Collection and assembly of data,
Naofumi Hashiguchi: Collection and assembly of data.
Masakazu Ishikawa: Data analysis.
Nobuo Adachi: Data analysis and interpretation, manuscript writing, reading of the article.
All authors read and approved the final manuscript.

Conflicts of interest

None declared.

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Abbreviations

ACL	anterior cruciate ligament
OTTR	over the top route
PL	posterolatetal

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