Over-the-Top Anterior Cruciate Ligament Reconstruction Using Single- or Double-Strand Hamstrings Autograft

ALBERTO RUFFILLI, MD; ROBERTO BUDA, MD; GHERARDO PAGLIAZZI, MD; MATTEO BALDASSARRI, MD; MARCO CAVALLO, MD; DEIANIRA LUCIANI, MD; ENRICO FERRANTI, MD; SANDRO GIANNINI, MD

abstract

The purpose of this study is to (1) report the long-term clinical and radiographic outcomes of a nonanatomical anterior cruciate ligament (ACL) reconstruction using an over-the-top (OTT) femoral route and (2) compare single-strand (1SHG) and double-strand (2SHG) hamstrings graft reconstruction. Fifty-one consecutive patients (mean age, 29.2±3.8 years) underwent nonanatomical ACL reconstruction using OTT femoral passage. Twenty patients underwent 1SHG reconstruction and 31 underwent 2SHG reconstruction. International Knee Documentation Committee (IKDC) score, Knee Injury and Osteoarthritis Outcome Score (KOOS), Tegner score, and KT-1000 (Medmetric Corporation, San Diego, California) evaluation were recorded at a mean follow-up of 12.1±1.6 years. At final follow-up, radiographic evaluation was performed according to the IKDC grading system. Mean IKDC subjective score at follow-up was 76.6±21.9 in the 1SHG group and 88.9±10.0 in the 2SHG (P=.009). Average KOOS was 82.6±18.7 in the 1SHG group and 92.4±9.2 in the 2SHG group (P=.016). Objective IKDC evaluation showed a higher percentage of normal knees in the 2SHG group (P=.018). Pivot shift testing revealed a significantly higher number of normal knees in the 2SHG group (P=.001). Radiographs showed fewer degenerative changes in the 2SHG group at final follow-up in the medial (P=.01) and lateral (P=.037) compartments. Nonanatomical ACL reconstruction using the OTT technique provided satisfactory results in terms of control of both static and dynamic instability at long-term follow-up, thus preventing degenerative joint disease. The 2SHG group showed better subjective and functional outcomes with fewer degenerative changes compared with the 1SHG group at long-term follow-up. [Orthopedics. 2015; 38(7):e635-e643.]

The authors are from the First Clinic of Orthopaedics and Traumatology, Rizzoli Orthopaedic Institute, Bologna University, Bologna, Italy.

The authors have no relevant financial relationships to disclose.

Correspondence should be addressed to: Gherardo Pagliazzi, MD, First Clinic of Orthopaedics and Traumatology, Rizzoli Orthopaedic Institute, Bologna University, Via Giulio Cesare Pupilli 1, 40136 Bologna, Italy (gherardo.pagliazzi@gmail.com).

Received: January 9, 2014; Accepted: August 27, 2014.

doi: 10.3928/01477447-20150701-64
Anterior cruciate ligament (ACL) reconstruction surgical techniques have changed over the decades. Restoration of long-term knee joint stability and function remains the basic principle of any treatment strategy to avoid serious sequelae such as meniscus and cartilage damage and, in particular, progression of knee osteoarthritis (OA).1-3

Studies have shown that patients undergoing ACL reconstruction have good clinical outcomes and knee function more than 10 years postoperatively, but the prevalence of knee OA following ACL reconstruction varies from less than 10% to more than 90%.4-10 A recent systematic review showed that studies with the highest methodologic quality reported up to a 13% incidence of radiographic tibiofemoral OA for isolated ACL injuries and between 21% and 48% in patients with combined ACL and meniscal injuries more than 10 years postoperatively.4-13

Data from the literature suggest that many factors work together to cause knee OA following ACL reconstruction, including the presence of associated chondral and meniscal lesions, the time elapsed between injury and reconstruction, and the age of the patient at the time of surgery.14

Recently, the literature has advocated the use of anatomic ACL reconstruction procedures, either single or double bundle, to restore knee kinematics and to guarantee anteroposterior and rotational stability, thus reducing the risk of long-term arthritis development.15-17 Nonanatomical ACL reconstruction with the over-the-top (OTT) femoral route, in which the graft is passed over the superomedial border of the lateral femoral condyle and fixed on the lateral femoral shaft, has been widely adopted in primary ACL reconstruction but also as a salvage option for revision cases and in skeletally immature patients. This technique has been demonstrated to be safe, simple, reproducible, and inexpensive.10,18 In addition, it has been recently proven that the OTT technique is able to obtain results comparable with those of anatomic single-bundle ACL reconstruction in terms of controlling the dynamic rotational instability, which is one of the main causes of long-term degenerative changes.18-20

The purpose of the current study is to report the long-term subjective, objective, and radiographic outcomes of a nonanatomical ACL reconstruction using the OTT femoral route and to compare single- and double-strand hamstrings graft reconstruction. The study also aimed to investigate the role of meniscectomy in the onset of arthritic changes at long-term follow-up. The hypothesis of the study was that double-strand OTT reconstruction may be able to adequately restore knee stability and kinematics, thus preventing arthritic changes at long-term follow-up.

**Materials and Methods**

**Patient Data**

Fifty-one consecutive patients (mean age, 29.2±3.8 years) undergoing a non-anatomical ACL reconstruction using the OTT femoral passage performed by the same surgeon (R.B.) between 1998 and 2000 were retrospectively reviewed. The OTT technique was routinely applied in authors’ clinical practice between 1998 and 2000 to repair primary ACL lesions. Patients with preoperative radiographic signs of arthritis, associated chondral lesions, axial deviation of the injured knee, and multidirectional instability were excluded from the study. A first group of 20 patients underwent a single-strand hamstrings graft (1SHG) reconstruction, and a subsequent group of 31 patients underwent double-strand hamstrings graft (2SHG) reconstruction. All patients were involved in sports activities. The 2 groups of patients were not significantly different regarding age, sex, body mass index, level of sport practiced, injury-to-surgery interval, and length of follow-up. Patient demographic data are presented in Table 1.
Preoperative Assessment

Preoperative evaluation included acquiring a complete history and physical and radiographic examinations, including magnetic resonance imaging (MRI) evaluation, to confirm the presence of an ACL lesion and to assess the presence of eventual associated lesions. International Knee Documentation Committee (IKDC) score, Knee Injury and Osteoarthritis Outcome Score (KOOS), and Tegner score were recorded.

SURGICAL TECHNIQUE

Preliminary arthroscopic evaluation was performed by anterolateral and anteromedial portals, under general or peripheral anesthesia, with the use of a tourniquet. Eventual meniscal lesions were treated with partial meniscectomy, and the ACL lesion was visualized. Anterior cruciate ligament remnants were carefully debrided. A vertical incision in the proximal medial metaphysis of the tibia was made to isolate the semitendinosus and gracilis tendons. The tendons were harvested carefully with a tendon stripper. As much of the tendon portion as possible was obtained while preserving the tibial insertion to ensure tibial fixation to the ascending portion of the graft. After removing the residual muscle tissue, the proximal third of the 2 tendons was tacked with 4 nonreabsorbable suture threads (No. 2 Ethibond; Ethicon, Somerville, New Jersey) (Figure 1).

A tibial tunnel was created with a guidewire starting 5 mm medially and 5 mm superiorly to the bone insertion of the gracilis tendon. The emergence of the tibial guidewire was guided by the residual of the torn ACL. The intraarticular emergence was placed at the center of the native footprint. The tibial tunnel was drilled using a cannulated reamer. The diameter of the tunnel depended on the size of the graft. A 7-mm reamer was used in single-strand reconstruction, and an 8-mm tunnel was used in double-strand reconstruction. A messenger wire was passed into the joint through the tibial tunnel and taken through the anteromedial portal. The lateral femoral condyle (LFC) was then exposed through a lateral incision. A second messenger wire was passed in the OTT position through the superolateral portion of the intercondylar groove and taken outside the tibial tunnel using the previous messenger wire. The graft was passed through the tibial tunnel and in the OTT position. Before graft fixation, no cyclic loading was performed. The graft was manually tensioned by an assistant and fixed with 1 or 2 titanium staples with the knee in 90° of flexion, a posterior drawer maneuver applied to the anterior tibial shaft, and the foot placed in external rotation (Figure 2).

In the 1SHG group, the graft remnant was resected (Figure 3), whereas in the 2SHG group, the remnant was taken backward (Figure 4) using a messenger wire, retrieved outside the tibial tunnel, and fixed by tenodesis at the level of the pes anserinus using nonresorbable stitches (Figure 5).

Postoperative Rehabilitation

Postoperatively, a rigid extension brace was worn overnight to avoid joint flexion contracture. The morning after surgery, the drainage was removed and the patient began continuous passive motion (CPM); the degree of joint movement allowed on the first day was between 0° and 40°. Thirty-six hours postopera-
tively, the patient was discharged and allowed to load the limb progressively, using the brace and 2 forearm crutches. The patient started a home rehabilitation program for the following 15 days aimed at obtaining full knee range of motion. After 2 weeks, full weight bearing was allowed without the brace. From the third to the fifth week, with the help of a physical therapist, the patient began rehabilitation, reaching the complete range of motion and performing closed-chain kinetic exercises aimed at increasing quadriceps strength up to 65% of the contralateral knee. Form the third to the ninth week, quadriceps strength was increased by performing open-chain kinetic exercises associated with proprioception recovery. At 3 months, running in a straight line was allowed. Return to competitive sports was allowed 6 months postoperatively.

Postoperative Evaluation

All patients were reassessed at a mean of 12.1±1.6 years. International Knee Documentation Committee score, KOOS, Tegner score were recorded. An arthrometric analysis using a KT-1000 (Medmetric Corporation, San Diego, California) was also performed using the manual maximum displacement test. A posteroanterior weight-bearing radiograph at 35° to 45° of flexion (tunnel view) was used to evaluate narrowing of the medial and lateral joint spaces. A Merchant view at 45° was used to document patellofemoral narrowing. Osteoarthritis degree was rated according to the IKDC knee examination form, with a mild grade (B) indicating minimal changes (ie, small osteophytes, slight sclerosis, or flattening of the femoral condyle) and detectable narrowing of the joint space, a moderate grade (C) indicating joint space narrowing up to 50%, and a severe grade (D) indicating joint space narrowing greater than 50%.

Statistical Analysis

All continuous data are expressed as mean±SD, and categorical variables are expressed as frequency and percentages. The Kolmogorov-Smirnov test was performed to test normality of continuous variables. Analysis of variance was performed to assess between-group differences of continuous and normally distributed and homoscedastic data; otherwise, the Mann-Whitney U test was used. The Kendall tau correlation was used to test the existence of an ordinal-by-ordinal correlation. Fisher’s chi-square test was performed to investigate the relationships between dichotomous variables. For all tests, a P value less than .05 was considered significant.

All statistical analyses were performed using SPSS version 19 statistical software (IBM Corp, Armonk, New York).

RESULTS

No intraoperative or immediate postoperative complications were observed. All associated meniscal lesions were

Table 2

<table>
<thead>
<tr>
<th>Demographic</th>
<th>Value</th>
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<td>Age, mean±SD, y</td>
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<tr>
<td>Sex, No.</td>
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<tr>
<td>Male</td>
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<td>Female</td>
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<tr>
<td>Medial</td>
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<tr>
<td></td>
<td>lesions of posterior horn, 3 radial lesions</td>
</tr>
<tr>
<td></td>
<td>at passage between body and posterior horn)</td>
</tr>
<tr>
<td>Lateral</td>
<td>4 (2 bucket-handle lesion, 2 longitudinal</td>
</tr>
<tr>
<td></td>
<td>lesions of posterior horn)</td>
</tr>
<tr>
<td>Medial and lateral</td>
<td>3 (2 bucket-handle lesions of medial meniscus</td>
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<tr>
<td></td>
<td>with longitudinal lesion of posterior horn</td>
</tr>
<tr>
<td></td>
<td>of lateral meniscus, 1 radial lesion of both</td>
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<td>medial and lateral meniscus)</td>
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<tr>
<td>Additional surgical procedure, No.</td>
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<td>(follow-up, mo)</td>
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<tr>
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<tr>
<td>Chondral debridement</td>
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<td>Level of sport practiced, No.</td>
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<td>Competitive</td>
<td>15</td>
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treated by partial meniscectomy. Details of the associated meniscal lesions and additional surgical procedures performed up to final follow-up are reported in Table 1 and Table 2.

At final follow-up, mean IKDC subjective score was 76.6±22.0 in the 1SHG group and 88.9±10.0 in the 2SHG group. Mean KOOS was 82.6±18.8 in the 1SHG group and 92.4±9.2 in the 2SHG group. The 2SHG group had statistically significantly better subjective IKDC scores and KOOSs at final follow-up than did the 1SGH group ($P$.018 and $P$.016, respectively).

A statistically significant higher number of normal knees was observed in the 2SHG group vs the 1SGH group ($P$.018) (Figure 6).

Regarding ligamentous stability, no differences were observed between the 2 groups with regard to the Lachman test and arthrometric evaluation (2.0±1.6 mm in the 1SHG group vs 1.5±1.3 mm in the 2SHG group), whereas a significantly higher incidence of rotational instability, evaluated by the pivot shift test, was observed in the 1SHG group ($P$.001) (Figures 7-8).

At final follow-up, 6 patients in the 1SHG group had resumed sports activities at a pre-injury level, 10 had resumed them at a lower level, and 4 had given them up. Twenty-four patients in the 2SHG group had resumed sport activities at a pre-injury level, 4 had resumed them at a lower level, and 3 had given them up.

Mean Tegner score in the 1SHG group was 6.95±1.5 preoperatively and 6.10±1.7 at final follow-up; in the 2SHG group, it was 7.26±1.3 preoperatively and 6.97±1.5 at final follow-up.

Regarding radiographic evaluation at final follow-up (Figures 9-11), a significantly higher occurrence of arthritis was observed in the 1SHG group vs the 2SHG group, in both the medial ($P$.01) and lateral ($P$.037) compartments (Figures 12-13).

The presence of associated meniscal lesions evaluated in the entire patient

Figure 6: International Knee Documentation Committee (IKDC) objective evaluation results showing a statistically significantly higher number of normal knees in the double-strand hamstrings graft (2SHG) reconstruction group vs the single-strand hamstrings graft (1SHG) reconstruction group.

Figure 7: Lachman test results showing no statistically significant differences between the 2 groups. Abbreviations: 1SHG, single-strand hamstrings graft reconstruction; 2SHG, double-strand hamstrings graft reconstruction.

Figure 8: Pivot shift test results showing better control of dynamic instability in the double-strand hamstrings graft (2SHG) reconstruction group. Abbreviation: 1SHG, single-strand hamstrings graft reconstruction.

Figure 9: Radiographic findings of the medial tibiofemoral joint showing a higher incidence of arthritic changes in the single-strand hamstrings graft (1SHG) reconstruction group. Abbreviation: 2SHG, double-strand hamstrings graft reconstruction.
cohort encompassed a significantly lower clinical subjective outcome according to IKDC score and KOOS with respect to patients without associated meniscal lesions ($P = .010$ and $P = .018$, respectively) and a significantly higher rate of arthritis occurrence in the medial, lateral, and patellofemoral compartments ($P = .001$, $P = .025$, and $P < .0005$, respectively).

Among the 33 patients affected by concomitant meniscal lesions, a higher incidence of arthritis was observed in the 1SHG group (14 of 20 patients) vs the 2SHG group (19 of 31 patients) ($P = .024$).

**DISCUSSION**

The results of this study demonstrate that the nonanatomical OTT technique with double-strand hamstrings graft is able to provide satisfactory subjective and objective outcomes at long-term follow-up, with a rate of arthritic onset comparable with that obtained by anatomical techniques using both hamstrings or patellar tendon grafts.$^{5-7}$

Many techniques have been described in the literature to reconstruct a torn ACL. The main goal of these procedures is to correct instability, thus preventing the onset of arthritic changes.$^{21-23}$ Many studies have emphasized the role of anatomic reconstruction in restoring knee stability.$^{24-27}$ The current study analyzed stability and arthritic onset at long-term follow-up after non-anatomical ACL reconstruction with the OTT femoral passage using single- or double-strand hamstrings graft. The OTT technique has many advantages vs anatomical techniques. It does not require the
creation of a femoral tunnel. The creation of the femoral tunnel, respecting the ACL native footprint, represents the most challenging aspect of ACL reconstruction; in fact, incorrect positioning of the femoral tunnel accounts for the majority of technical failures following ACL reconstruction.\textsuperscript{28–32} In addition, the OTT technique spares the bone stock on the femoral side, which assumes importance in cases of revision surgery involving the femoral tunnel. The technique is also inexpensive, requiring only one staple for graft fixation, and it may be useful in cases of revision where the femoral bone stock is severely reduced or in cases of pediatric ACL reconstruction.\textsuperscript{18–20}

These findings are in line with those described by Karlson et al,\textsuperscript{33} who reported no differences in the outcome between through-the-condyle and OTT graft placements in primary ACL reconstruction. In addition, in a recent comparative study by Zaffagnini et al\textsuperscript{34} using a surgical navigation system dedicated to kinematic assessment, the nonanatomical OTT technique worked similarly to anatomic double-bundle reconstruction in the control of static knee laxity.

Verdano et al\textsuperscript{35} reported comparable clinical outcomes between the OTT technique and double-bundle ACL reconstruction in a series of 40 patients evaluated at 4-year follow-up.\textsuperscript{35} A recent study by Asai et al\textsuperscript{20} on the use of a triaxial accelerometer showed comparable control of dynamic instability using either anatomical reconstruction or OTT femoral passage in 8 fresh-frozen human cadaveric knees.

In the current study, the 2SHG group achieved a mean IKDC subjective score of 88.9±10.0 and a mean KOOS score of 92.4±9.2. Leys et al\textsuperscript{16} and Mascarenhas et al,\textsuperscript{33} using anatomical ACL reconstruction with both patellar and hamstrings grafts, reported excellent clinical results in line with the findings of the current study, with an average IKDC score ranging from 85 to 94 points at long-term follow-up. Studies by Lebel et al\textsuperscript{38} and Möller et al\textsuperscript{39} describing anatomical reconstruction with a patellar tendon graft reported clinical results in line with the findings of the current study, with an average IKDC score ranging from 80 to 92 points at more than 10 years of follow-up. In the current study, regarding the evaluation of knee stability in the 2SHG group, 74% of patients were rated normal (A) according to the Lachman test and the remaining 26% were rated nearly normal (B). Dynamic stability, evaluated by the pivot shift test, was normal (A) in 68% of patients and nearly normal (B) in 26% of patients. These results are comparable with those obtained by Struwer et al,\textsuperscript{40} Leys et al,\textsuperscript{36} and Mascarenhas et al\textsuperscript{17} with anatomical ACL reconstruction using hamstrings or patellar tendon grafts. Finally, the rate of arthritic changes in the 2SHG group at final follow-up was in line with the outcomes of anatomical ACL reconstruction techniques as reported by Claes et al\textsuperscript{41} in a recent meta-analysis.

Nonanatomical reconstruction with the OTT femoral passage performed using a single-strand graft showed significantly worse results in both subjective and objective scores. In addition, a significantly higher rate of arthritis was observed at final follow-up. This finding seems to be directly connected to the higher rate of dynamic instability, testified by the higher values observed with the pivot shift test in these patients. Statistical evaluation of the results highlighted the correlation between dynamic instability and arthritis progression, as previously described by Wong et al\textsuperscript{42} and Ayeni et al.\textsuperscript{43}

It is not clear why more instability was noted in the 1SHG group vs the 2SHG group, but it may be related to lower mechanical graft strength or less cross-sectional area of the graft within the intercondylar notch, both of which are inherent to single-strand reconstruction.

The presence of meniscal lesions proved to be an important prognostic factor, showing a strong correlation with lower subjective clinical outcomes and the onset of degenerative changes of the joint, as previously described by many authors.\textsuperscript{44,45} Patients with concomitant meniscal lesions and undergoing single-strand reconstruction showed a higher rate of arthritic changes at follow-up compared with patients in the 2SHG group. This finding emphasizes the need to use double-strand hamstrings graft reconstruction to obtain satisfactory control of knee instability, thus preventing degenerative changes at follow-up.

This study has some limitations. It is retrospective, and the sample size is small. Also, despite an objective validation of static stability by means of the KT-1000 arthrometer, an objective evaluation of dynamic instability is lacking.\textsuperscript{46}

**Conclusion**

Nonanatomical ACL reconstruction using the OTT technique provided satisfactory results in terms of control of both static and dynamic instability at long-term follow-up. However, the 2SHG group showed better subjective and functional outcomes with fewer degenerative changes at long-term follow-up compared with the 1SHG group. Therefore, double-strand hamstrings graft reconstruction is recommended when performing nonanatomical ACL reconstruction using the OTT technique.

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