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Arthroscopic anatomical double bundle anterior cruciate ligament reconstruction: A prospective longitudinal study

Ashish Devgan, Amanpreet Singh, Paritosh Gogna, Rohit Singla, Narender Kumar Magu, and Reetadyuti Mukhopadhyay

Department of Orthopaedics and Rehabilitation, PGIMS, Rohtak, Haryana, India

Address for correspondence: Dr. Paritosh Gogna, 2/11-J (UH), Medical Enclave, PGIMS, Rohtak - 124 001, Haryana, India. E-mail: paritosh.gogna@gmail.com

Abstract

Background:

Single bundle anterior cruciate ligament (ACL) reconstruction has been the current standard of treatment for ACL deficiency. However, a significant subset of patients continue to report residual symptoms of instability with a poor pivot control. Cadaveric biomechanical studies have shown double bundle (DB) ACL reconstructions to restore the knee kinematics better. This study evaluates the outcome of DB ACL reconstruction.

Materials and Methods:

30 consecutive patients who underwent anatomic DB ACL reconstruction were included in this prospective longitudinal study. There were all males with a mean age of 25 ± 7.45 years. All patients were prospectively evaluated using GeNouRoB (GNRB) arthrometer, functional knee scores (International Knee Documentation Committee [IKDC] and Lysholm) and postoperative magnetic resonance imaging (MRI) for comparing the graft orientation and footprint of the reconstructed ACL with that of the normal knee.

Results:

The average followup was 36.2 months. At the time of final followup the mean Lysholm score was 93.13 ± 3.31. As per the objective IKDC score, 26 patients (86.6%) were in Group A while 4 patients (13.3%) were in Group B. The mean differential anterior tibial translation by GNRB, arthrometer was 1.07 ± 0.8 mm (range 0.1-2.3 mm). All cases had a negative pivot shift test. MRI scans of operated and the contralateral normal knee showed the mean sagittal ACL tibial angle coronal ACL tibial angle and tibial ACL footprint to be in accordance with the values of the contralateral, normal knee.

Conclusion:

The study demonstrates that DB ACL reconstruction restores the ACL anatomically in terms of size and angle of orientation. However, long term studies are needed to further substantiate its role in decreasing the incidence of early osteoarthritic changes compared to the conventional single bundle reconstructions.

Keywords: Arthroscopy, anterior cruciate ligament, reconstruction, double bundle
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Introduction

Anterior cruciate ligament (ACL) tears are one of the most common knee injuries and single bundle (SB)

ACL reconstruction has been the traditional treatment since long.[1,2] Although results of SB ACL reconstruction have been good, numerous studies indicate superiority of double bundle (DB) reconstruction in terms of overall stability and better knee scores.[3,4] Biomechanical studies indicate that SB reconstruction does not fully restore normal knee kinematics and that each bundle (anteromedial (AM) and posterolateral (PL)), makes a unique contribution to knee function wherein AM bundle provides the major anterior restraint and the PL bundle contributes to rotational stability.[3,4,5,6]

There are still many controversies concerning the surgical techniques in anatomic DB reconstruction, namely in procedures for creating anatomic tunnels, graft preparation, tensioning and fixation[3,4,5,6,7,8] and therefore utility of anatomic DB reconstruction has not yet been fully established. Recently, anatomic DB reconstruction has been the center of interest as studies have postulated that it not just simply creates two mechanical bundles, but imparts best possible knee kinematics and stability.[4,6,8,9] This study evaluates outcome of antatomic double bundle reconstruction and identifies whether DB is truly anatomical.

Materials and Methods

30 clinicoradiologically proven cases of ACL rupture treated with DB recnstruction were included in this prospective study. Exclusion criteria were, patients with any additional ligament injury or any previous knee ligament surgery, small native ACL usually an insertion site <14 mm, severe bone bruising, a narrow notch, severe arthritic changes, malalignment or abnormal contralateral knee.[10]

The patients underwent a preoperative assessment including a history, clinical examination, knee examination (Lachman test, Pivot shift), Lysholm score, International Knee Documentation Committee (IKDC) scale (subjective as well as objective), standard radiograph (AP and lateral view) and Magnetic Resonance Imaging (MRI).

The Lysholm knee score is a measure of knee function, symptoms and disability. This questionnaire consists of eight questions, with closed answers alternatives, of which final score is expressed nominally and ordinally, with a score ranging from 95 to 100 points regarded as “excellent”; 84-94 points, “good,” from 65 to 83 points, “fair,” and “poor” when values are equal or below 64 points. Recording of the Lysholm score was done preoperatively and postoperatively.[11]

The IKDC rating scale consists of both a subjective questionnaire and an objective evaluation.

Objective international knee documentation committee scale

The objective IKDC scale has total of seven domains related to the knee, reflecting both impairment and disability. The worst grading for first three key domains – presence of effusion, knee range of motion (ROM) and ligament stability – determines the eventual IKDC grade. Patients are graded in four different grades – A, B, C and D – normal, nearly normal, abnormal, and severely abnormal, respectively.[12]

All patients underwent arthroscopic DB ACL reconstruction under regional anesthesia after obtaining written consent from the patients.

Operative procedure

A diagnostic arthroscopy was performed to confirm the ACL tear and other findings (meniscal or chondral injury). The ruptured ACL was examined with an arthroscopic probe, dissected and debrided. The tibial footprint of the ACL was left intact. A bony notchplasty was not routinely performed. The femoral footprint was identified and minimally debrided. While viewing at 90° of knee flexion, “lateral bifurcate ridge” is often seen on the femoral insertion between the AM and PL bundles, whereas a “lateral intercondylar ridge” is often seen on the upper limit of both the AM and PL bundles. These are useful surgical landmarks in addition to the native insertion fibers.[13,14]

Semitendinosus and gracilis tendons were harvested and prepared. The mean total length obtained for semitendinosus was 25 cm and for gracilis tendon it was 20 cm. The semitendinosus tendon (for the AM bundle) and the gracilis tendon (for the PL bundle) were looped separately over closed loop Endobutton. The thickness of the graft construct was measured using a tendon thickness measuring gauge to the nearest of 0.5 cm. Drilling of the AM femoral tunnel was done through the AM portal with the knee bent 90° to place the guide. Appropriate-sized endoscopic reamer was selected according to the graft diameter and the AM femoral socket was made. Depth was regulated according to the desired insertion length and was 9-10 mm greater than the desired graft insertion to allow for the Endobutton flip [Figure 1].

The femoral PL tunnel was drilled with the knee flexed to 120° and anatomic anterior cruciate ligament reconstruction (ACLR) PL femoral aimer (Smith and Nephew, Andover, United states of America) inserted with an appropriate sized post into the already made AM tunnel. It was ensured that the shoulder of the AM post was in contact with the lateral wall of the intercondylar notch. In all our cases, the length of the AM tunnel ranged between 40 and 50 mm and the length of the PL tunnel ranged between 30 and 35 mm.

Smith and Nephew ACUFEX Director ACL tip aimer (Smith and Nephew, Andover, United states of America) was set at 55° for the placement of the anteromedial guide wire. The AM tibial tunnel in the anatomic DB reconstruction technique is more anteriorly located than in SB reconstruction. Appropriate sized post on Smith and Nephew anatomic ACLR PL tibial aimer was used. Once the post was secured, it was inserted into the AM tibial tunnel until the distal end was flush with the tibial surface [Figure 2]. This slot was oriented to align with the anticipated center of the PL bundle. The PL tunnel had a more medial and distal entry point on the tibial cortex than a standard ACL tibial tunnel. An osseous bridge of approximately 2-3 mm was left between the two tunnels inside the joint.

Finally, the grafts were passed [Figures 3–5], the Endobutton device was flipped, and the fixation was tested. It was ensured that full ROM was achieved after fixation of the AM and PL bundles and that there was no impingement within the intercondylar notch, neither with the lateral condyle wall in full extension nor with the posterior cruciate ligament in full flexion. Postoperatively, the knee was immobilized with a knee immobilizer brace in full extension. Immediate quadriceps and hamstrings exercises were started.

The fixation method used on the tibial side was titanium interference screw (Hib Surgicals, India Pvt. Ltd.) for both tunnels and augmentation with tendon staple [Figure 6]. AM bundle was fixed in 60° flexion and the PL bundle was fixed in full extension. Immediate quadriceps and hamstring exercises started and partial weight bearing was allowed with crutches/walker in first postoperative week. After first week; range of motion in arc of 0-90˚ (closed kinetic chain) was started. Full weight bearing was allowed by 3-4 weeks and running and cycling after one month. The patient was followed up at 2 weeks for suture removal thereafter fortnightly for 2 months, monthly for next 3 months and then once in 6 months for clinical evaluation and complications if any.

At the time of final followup examination of the knee (Lachman, Pivot shift, ROM) was done along with quantitative assessment of anterior tibial translation using GeNouRoB (GNRB), an alternative anterior knee laxity measurement device [Figure 7]. The lower limb was placed in a rigid support with the knee at 0° of rotation, the restraining power being recorded. A 134 N thrust force was transmitted by a jack to the upper segment of the calf. It was assured that while the force was being applied, there was no hamstring muscles contraction. Displacement of the anterior tibial tubercle was recorded using a sensor with a 0.1 mm precision.[15] Functional evaluation was done according to the Lysholm score and IKDC scale (subjective and objective).

Bilateral knee MRI was done for visualization of the ACL bundle anatomy and the appearances of graft components and graft orientation and compare it with the normal ACL of the contralateral knee at final followup[16] [Figure 8]. The coronal oblique sequence with thin sections (2.5-mm slice thickness) or the use of 3-T imaging can differentiate the two bundles as discrete entities. In our institution, we obtained MRI on a 1.5-T magnet and utilized coronal oblique sequence with thin sections for visualization of the same. The following parameters were evaluated:

1. Sagittal ACL-tibial angle: This is the angle between a line paralleling the midlateral tibial plateau and a line demarcating the anterior most margin of the ACL, drawn on the midline image best depicting the ACL. Normal value for patients with closed physes is (58.8° ± 4.9°).
2. Coronal ACL tibial angle: This is the angle between a line demarcating the medial most margin of the long axis of the ACL and a line connecting the medial and lateral most margins of the tibial

plateau on the same section. Normal value for patients with closed physes is 69.1° ± 7.4°.

3. ACL Foot print: ACL footprint size was measured in sagittal midline section and compared with opposite normal knee.[17]

Statistical analysis

Data were analyzed using the IBM SPSS version 19 (IBM, New York, United states of America). Preoperative values and values at the final followup were compared using paired *t*-test. $P < 0.05$ was considered to be statistically significant.

Results

All patients were males with mean age of 25 ± 7.45 years (range 18-44 years). The right side was involved in 80% cases ($n = 24$). The mode of trauma was sports injury ($n = 22$) and road traffic accident ($n = 8$). The pivoting stress was found to be the most common cause of ACL rupture in our series ($n = 14$, 46.6%). Isolated ACL tear was present in 16 cases (53.3%) and the rest of 14 cases (46.6%) were associated with meniscus injury. 22 patients (73.3%) presented with a feeling of giving way of the knee during routine work and guarded walking due to apprehension usually without pain, while 8 patients (26.6%) had the feeling of giving way only during sporting activity usually with pain. The mean followup was 36.2 months (range 24-46 months).

Mean preoperative Lysholm score was 46.33 ± 12.12, which improved to 93.13 ± 3.31 at the time of the final evaluation and 22 cases (73.3%) had excellent results, while 8 cases (26.6%) had a good result. The mean preoperative subjective IKDC score was 43.52 ± 9.20, which improved to 92.87 ± 2.78 at the final followup. According to postoperative objective IKDC score, 26 patients (86.6%) were in Group A and 4 patients (13.3%) were in Group B.

In this study mean differential anterior tibial translation was 1.07 ± 0.80 mm (range 0.1-2.3 mm) [Figure 9]. Though most of the patients ($n = 26$, 86.6%) regained very good ROM (0-120° or above), 4 (13.3%) cases had mean 15° loss of terminal flexion. No patient had terminal extension loss. All the patients showed a negative pivot shift tests.

6 cases (20%) complained of mild intermittent knee pain while 2 cases (6.6%) developed superficial infection, which healed with antibiotics and daily dressings. In 2 cases (6.66%) Endobutton was flipped (>3 mm) in soft tissue outside the femoral cortex, while in 4 cases (13.3%) there was sensory loss over upper medial tibia due to the involvement of the infrapatellar branch of saphenous nerve.

Magnetic resonance imaging scans of operated and the contralateral normal knee showed the mean sagittal ACL tibial angle [Figure 8a and d] of 56.1° ± 5.06° in the operated knee, which was in the range of normal values in literature (58.8° ± 4.9°) and were comparable to the values of ACL in the contralateral normal knee. The mean coronal ACL tibial angle (74.86° ± 5.69°) [Figure 7b and e] and mean sagittal tibial ACL footprint [Figure 8c and f] of the graft (12.65 mm ± 1.93) too was in the range of normal values in literature and comparable to the values of contralateral normal knee [Table 1].

Discussion

Analysis of data from the last 10 years reveals that after anatomical single bundle ACL reconstruction, 10% to 30% patients complain of pain and residual instability.[18] and no >60% of the patients make a full recovery after their ACL reconstruction.[19]

Double bundle construct has been shown to regain a structure that morphologically and functionally closely resembles a normal ACL.[6] As a result; several centers have attempted to improve upon the single bundle technique by reconstructing both the anteromedial and the posterolateral bundles of the ACL.

In our study, the mean preoperative Lysholm score was 46.3 ± 12.12 which is quite less as compared to the observations of Fujita *et al.*[20] and Järvelä[21] who reported a preoperative Lysholm score of 67.4 and 69, respectively. This could be attributed to the fact that the majority of patients in our country get diagnosed late; the instability and its associated secondary damage in the knee due to delayed presentation may be the reason for a very low preoperative Lysholm score in our patients. Our mean postoperative Lysholm score and postoperative subjective IKDC score, of 94.13 ± 3.31, 92.87%, respectively are in close proximity with those reported by Siebold *et al.*[22] (90% and 88%) and Asagumo *et al.*[7] (96.8% ± 5.1 and 85%). In our study, 100% cases reported their knees as normal or near normal (grade A + B objective IKDC) after reconstruction and so was the case with Järvelä[21] (100%), Siebold *et al.*[22] (97%) and Kim *et al.*[23] (91%).

Our results are consistent with those of previous authors, indicating excellent restoration of anterior and rotatory stability for most patients.[7,8] Though Lachman test is a reliable clinical test for diagnosis of ACL rupture, quantification of anteroposterior tibial displacement still remains inaccurate. It is only possible using a mechanical, radiographic or electromagnetic system. Laximetry reproducibility is significantly better with the GNRB than with the KT-1000 because its displacement transducer precision (0.1 mm) is higher than that of the KT-1000 (1 mm).[15] In this study differential anterior tibial translation (when compared with normal knee) was 1.07 mm, which was in accordance with studies conducted by Yasuda *et al.*[8] and Siebold *et al.*[22] 1.0 mm each and was far better than the rest of the studies on DB and SB ACL reconstruction [Table 2]. No patient in our study reported instability during activities of daily living or doing strenuous activities.

Achieving rotatory control of the knee post ACL reconstruction has been shown to increase patient satisfaction, decrease functional instability and potentially delay the development of osteoarthritis. The pivot shift is able to assess this rotatory component of knee laxity and appears to have the potential to become a benchmark in gauging the success of ACL surgery.[27] In this study, all patients were pivot shift negative after DB ACL reconstruction, which is comparable with the study conducted by Järvelä[21] and Kim *et al.*[23] in the recent past and was slightly better than Siebold *et al.*[22] and Tohyama *et al.*[25] (97% each). We saw a significant improvement of rotational stability according to the pivot shift, which might be related to the additional PL bundle reconstruction and the differential tightening of the two bundles of the graft. One could also speculate that the high number of negative pivot shift tests might also be related to the four tunnel technique, which increases the size of the footprint of the reconstruction. However, the pivot shift test is a subjective clinical tool to assess rotational stability and unfortunately, we still lack an accurate objective measurement method.

Nevertheless, all good things come with a price; DB technique also has its own concerns. Because there are more tunnels in a DB technique, there are concerns regarding difficulties in revision ACL reconstruction. One concern relates to tunnel enlargement, which can hamper ACL revision surgery because of the potential need for a staged reconstruction in which the tunnels are bone grafted first, followed by the actual revision surgery performed after the bone graft has been incorporated.[28] Tunnel communication can also occur when drilling the tunnels if they are placed too close to each other.[29,30] Because there are more tunnels to be created and more grafts to be fixed, the DB technique can be associated with more technical difficulties than the traditional single bundle technique. The DB ACL reconstruction can be a technically demanding procedure, with increased costs due to more fixation material, grafts and a longer operative period.

Footnotes

Source of Support: Nil

Conflict of Interest: None.

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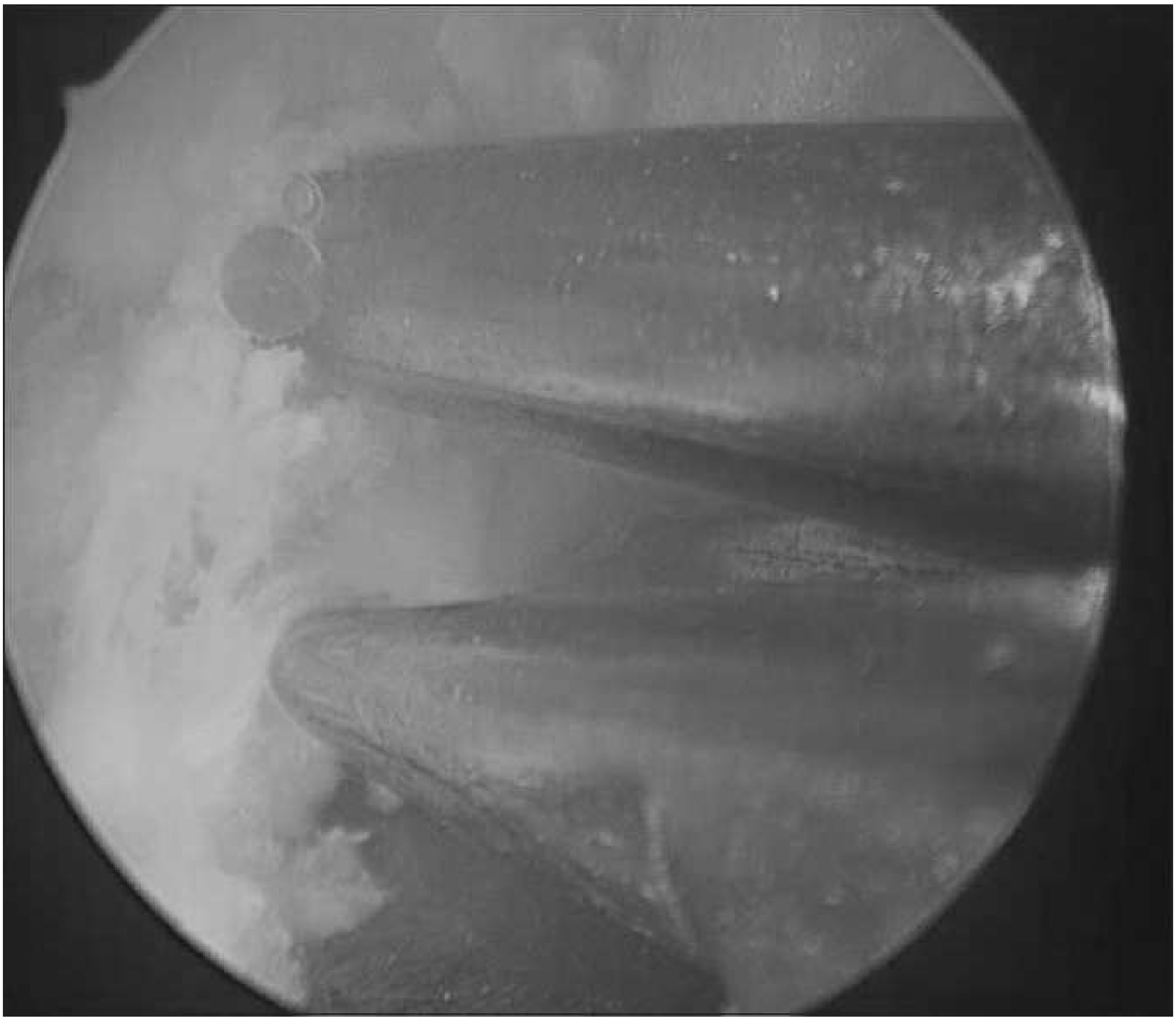
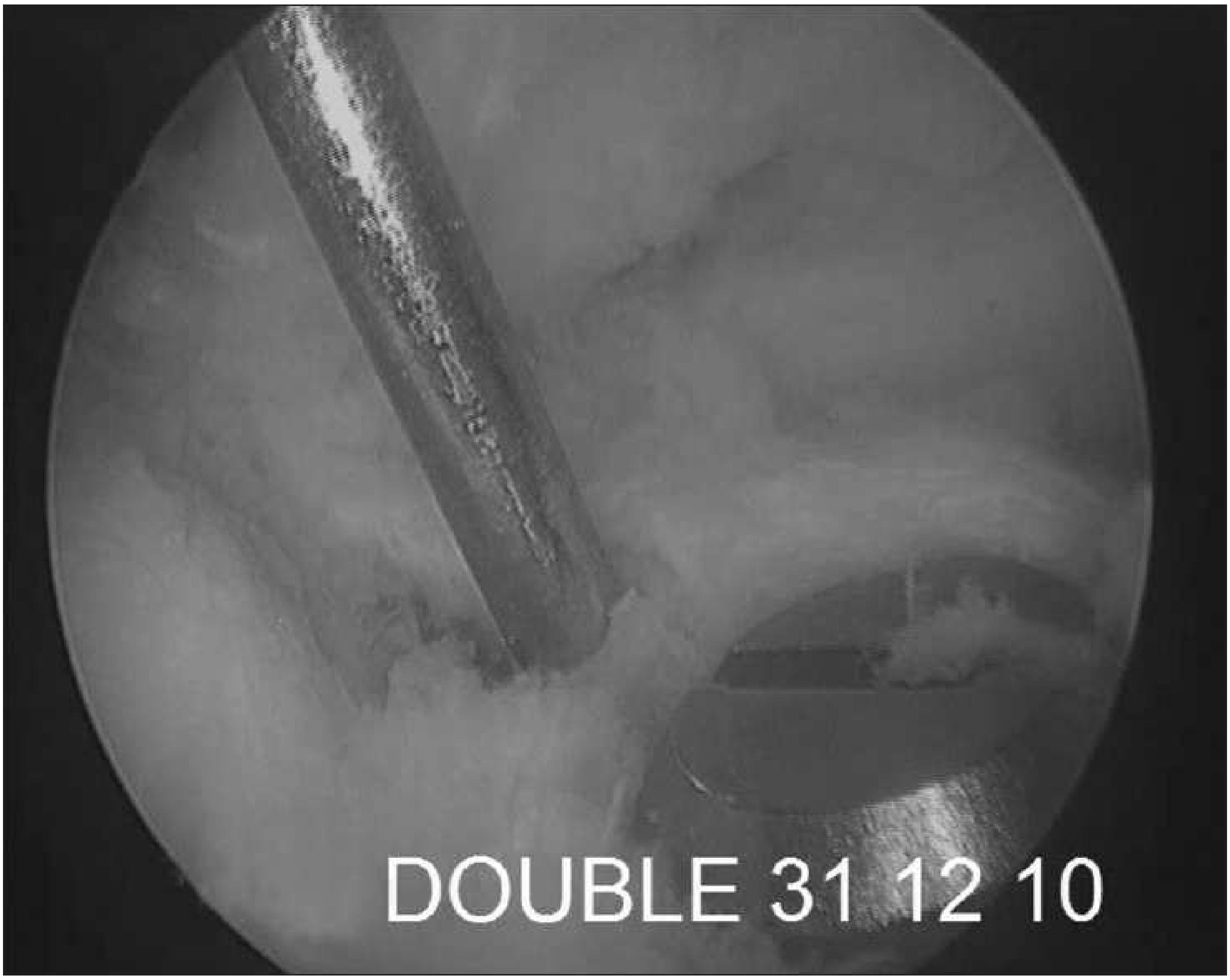
Figures and Tables

Figure 1



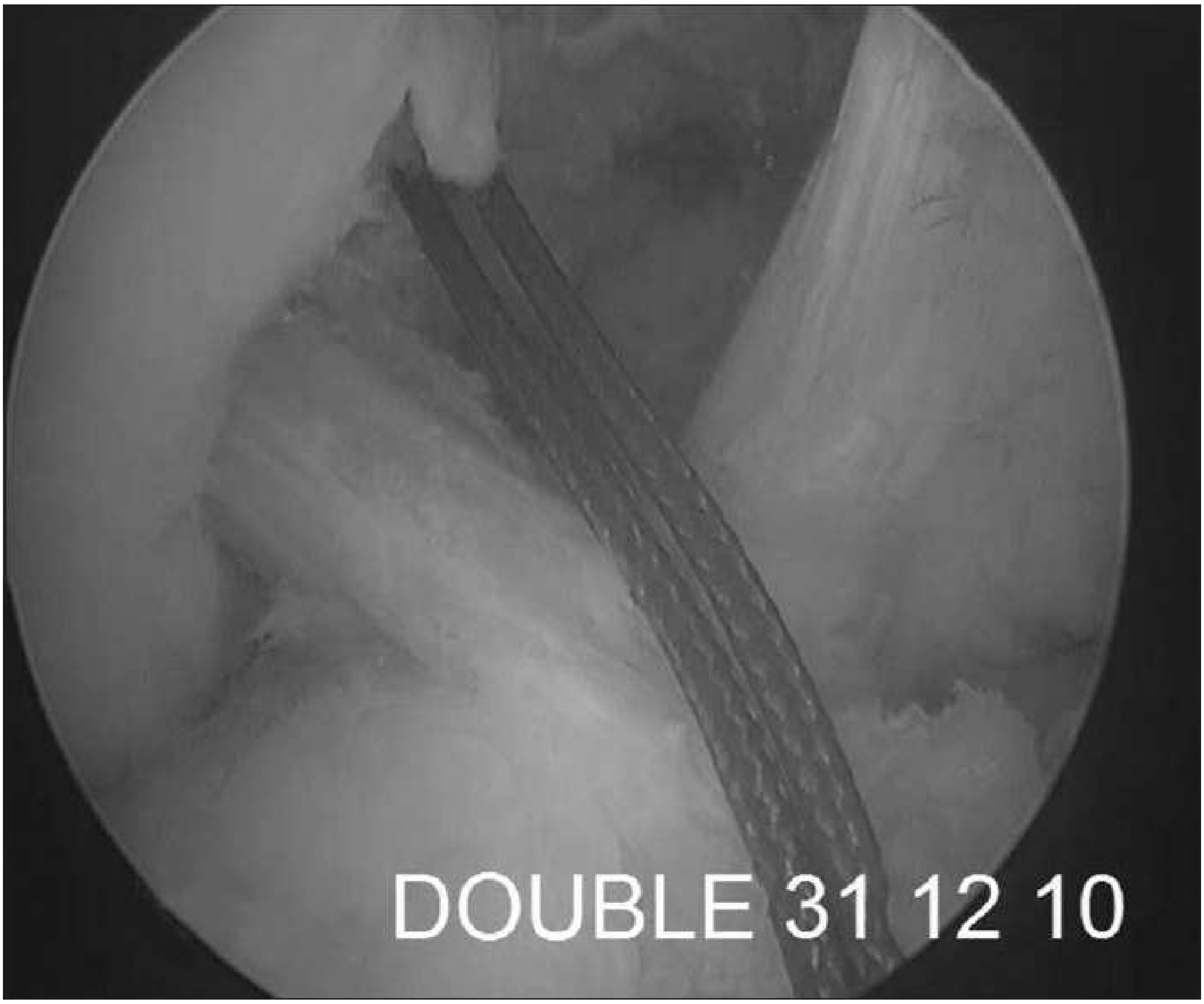
Arthroscopic view showing drilling of femoral tunnels

Figure 2



Arthroscopic view showing drilling of tibial tunnels

Figure 3

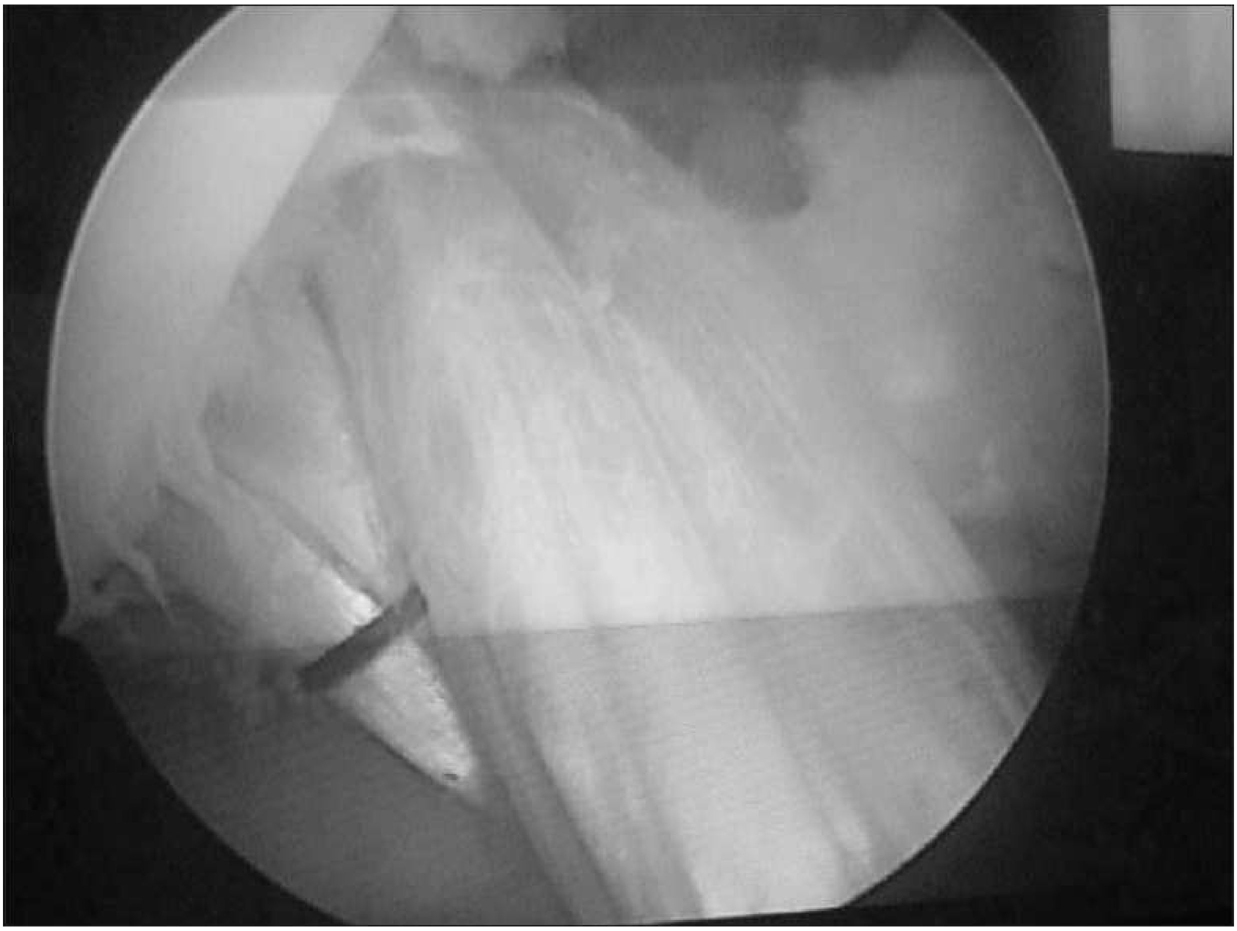


Arthroscopic view showing passage of anteromedial graft

Figure 4

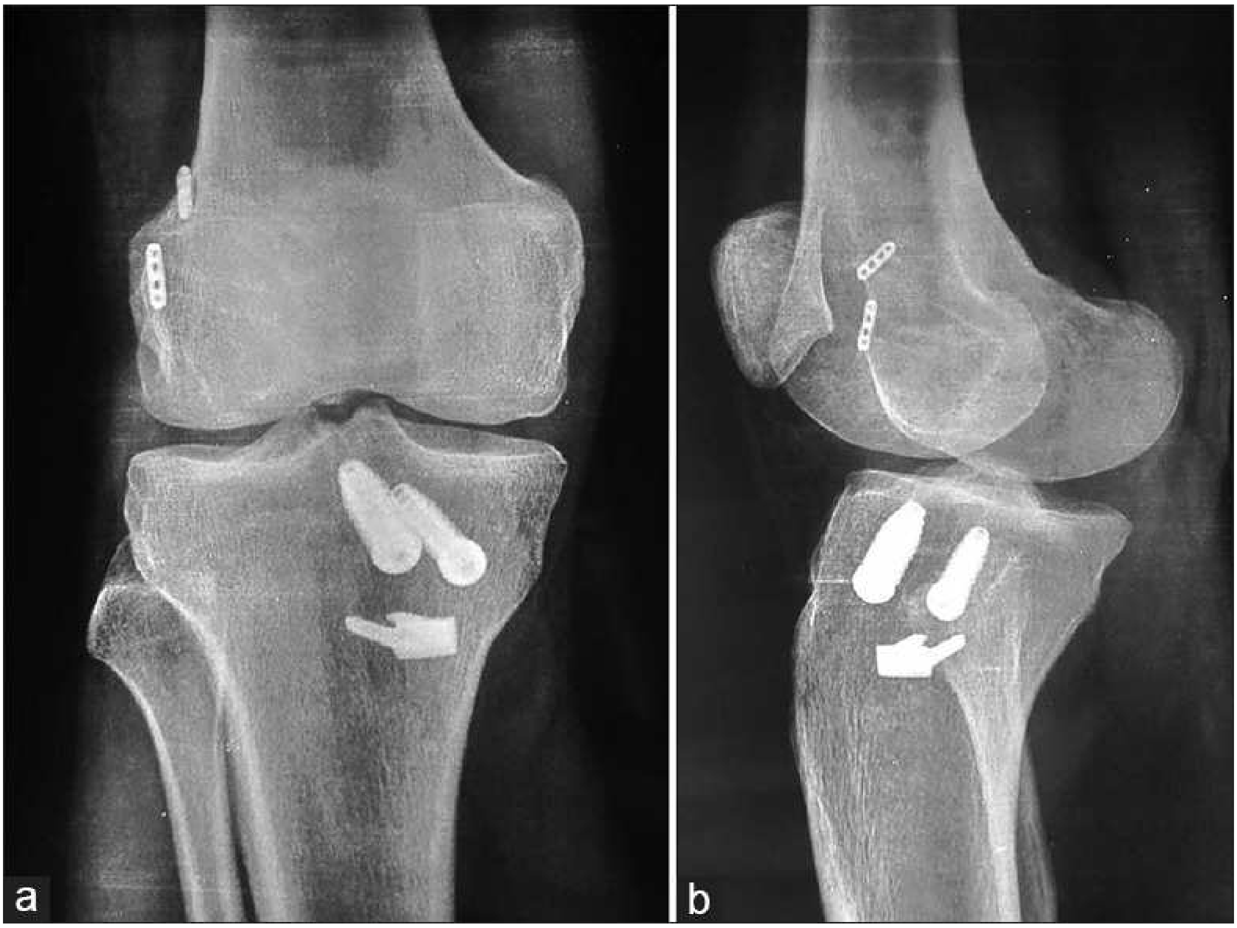
Arthroscopic view showing passage of postrolateral graft

Figure 5



Arthroscopic view showing both anteromedial and postrolateral graft

Figure 6



(a) anteroposterior and (b) lateral radiographs of a 28 year old male who underwent double bundle anterior cruciate ligament reconstruction

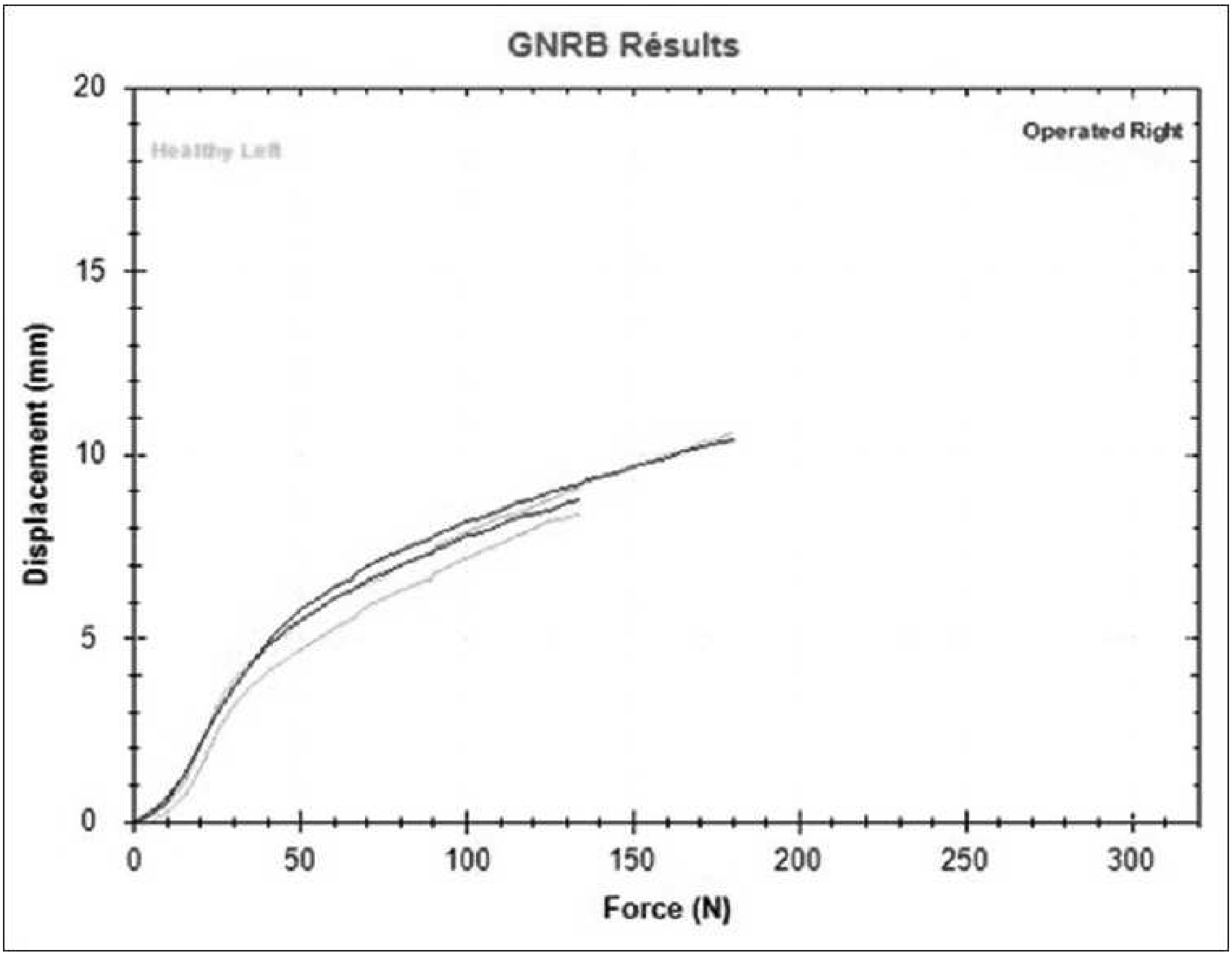
Figure 7

Clinical photograph of GeNouRoB arthrometer

Figure 8

Magnetic resonance imaging (MRI) of the operated knee of a 26 year old male showing (a) Sagittal anterior cruciate ligament (ACL) angle 52.1° (b) coronal ACL angle of 78.4° and 73.4° (c) tibial ACL footprint as 13.6 mm and 12.3 mm. MRI of the normal knee of the same patient showing (d) sagittal ACL angle 49.7° (e) coronal ACL angle 73.4°

Figure 9



Graphical representation of anterioposterior translation of the operated knee as measured by GeNouRoB

Table 1

Parameter	Normal knee	Operated knee	*P* value
Sagittal tibial ACL foot print	12.38±0.64	12.65±1.93	0.7741*
Sagittal tibial ACL angle	55±4.68	56.1±5.06	0.7103*
Coronal tibial ACL angle	69.6±5.2	74.86±5.69	0.1478*

*P>0.05 difference is considered to be not statistically significant. MRI=Magnetic resonance imaging, ACL=Anterior cruciate ligament

Postoperative MRI evaluation for graft orientation

Table 2

Authors	Mean differential anterior tibial translation in double bundle ACL group (mm)	Mean differential anterior tibial translation in single bundle ACL group (mm)
Siebold *et al.*[22] (2008)	1	1.6
Yasuda *et al.*[8] (2004)	1.1	2.8
Aglietti *et al.*[24] (2010)	1.2	2.1
Tohyama *et al.*[25*] (2011)	1.5	-
Muneta *et al.*[26] (2007)	1.4	2.4
Kim *et al.*[23] (2009)	1.79	2.64
Fujita *et al.*[20] (2011)	1.5	2.2
Järvelä[21] (2007)	1.6	1.7
Present study*	1.07	-

*These studies were not comparative for DB and SB. ACL=Anterior cruciate ligament, DB=Double-bundle, SB=Single-bundle, GNRB=GeNouRoB

Differential anterior translation as compared to normal knee by GNRB arthrometer