Outcome of double bundle anterior cruciate ligament reconstruction using crosspin and aperture fixation

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Abstract
Background: Double bundle anterior cruciate ligament (DBACL) reconstruction is said to reproduce the native anterior cruciate ligament (ACL) anatomy better than single bundle anterior cruciate ligament, whether it leads to better functional results is debatable. Different fixation methods have been used for DBACL reconstruction, the most common being aperture fixation on tibial side and cortical suspensory fixation on the femoral side. We present the results of DBACL reconstruction technique, wherein on the femoral side anteromedial (AM) bundle is fixed with a crosspin and aperture fixation was done for the posterolateral (PL) bundle.

Materials and Methods: Out of 157 isolated ACL injury patients who underwent ACL reconstruction, 100 were included in the prospective study. Arthroscopic DBACL reconstruction was done using ipsilateral hamstring autograft. AM bundle was fixed using Transfix (Arthrex, Naples, FL, USA) on the femoral side and bio interference screw (Arthrex, Naples, FL, USA) on the tibial side. PL bundle was fixed on femoral as well as on tibial side with a biointerference screw. Patients were evaluated using KT-1000 arthrometer, Lysholm score, International Knee Documentation Committee (IKDC) Score and isokinetic muscle strength testing.

Results: The KT-1000 results were evaluated using paired t test with the P value set at 0.001. At the end of 1 year, the anteroposterior side to side translation difference (KT-1000 manual maximum) showed mean improvement from 5.1 mm ± 1.5 preoperatively to 1.6 mm ± 1.2 (P < 0.001) postoperatively. The Lysholm score too showed statistically significant (P < 0.001) improvement from 52.4 ± 15.2 (range: 32-76) preoperatively to a postoperative score of 89.1 ± 3.2 (range 67-100). According to the IKDC score 90% patients had normal results (Category A and B). The AM femoral tunnel initial posterior blow out was seen in 4 patients and confluence in the intraarticular part of the femoral tunnels was seen in 6 patients intraoperatively. The quadriceps strength on isokinetic testing had an average deficit of 10.3% while the hamstrings had a 5.2% deficit at the end of 1 year as compared with the normal side.

Conclusion: Our study revealed that the DBACL reconstruction using crosspin fixation for AM bundle and aperture fixation for PL bundle on the femoral side resulted in significant improvement in KT 1000, Lysholm and IKDC scores.

Key words: Anterior cruciate ligament, double bundle reconstruction, fixation technique

Introduction
Single bundle anterior cruciate ligament (SBACL) reconstruction has been the gold standard for decades.1-3 Double bundle anterior cruciate ligaments (DBACL) reconstruction is said to replicate the native anatomy of the anterior cruciate ligament (ACL). Several biomechanical studies suggest that double-bundle ACL reconstruction (ACLR) has advantages in providing both anterior and rotational stability in the ACL-deficient knee compared with single-bundle ACLR. Hence, currently, there is more focus on double-bundle ACLR than single-bundle reconstruction.4-7 Yet it is not conclusively proven that DBACL reconstruction leads to better functional results when compared with SBACL reconstruction.8-11

In DBACL, four tunnels are drilled, which makes it technically more demanding. Soft tissue grafts have been the most popular for double bundle ACLRs and a secure fixation technique is needed to withstand the forces on the graft in the rehabilitation period.12 Commonly used techniques for fixation include suspensory fixation such as endobutton or crosspin fixation and aperture fixation with interference screw. In recent years, a large number of fixation devices for hamstring graft have been proposed. Femoral fixation can be achieved with the use of several devices with different
mechanical properties. Fixation methods in DBACL reconstruction should overcome technical difficulty of graft fixation in two adjacent tunnels especially on the femoral side without compromising on fixation strength.

We evaluated results of a technique where tibial side of both anteromedial (AM) and posterolateral (PL) bundle had aperture fixation (bio interference screw) while on the femoral side AM bundle was fixed with crosspin and PL bundle had aperture fixation (bio interference screw).

**Material and Methods**

A prospective study was done with 157 patients of ACL deficient knees between January 2008 and November 2010. Patients were sequentially selected for the study after thorough clinical examination using the Lachman and Pivot shift test. They were evaluated using the KT–1000 arthrometer and isokinetic muscle testing and preoperative IKDC scores were documented. Antero-posterior and lateral radiographs were obtained in all cases. DBACL reconstruction was done using ipsilateral semitendinosus and gracilis tendon autograft. A total of 30 patients did not turn up for regular followup of 1 year and 27 patients had associated chondral lesions requiring additional procedures and were thus excluded from the study. 100 patients were followedup for a minimum of 1 year. Inclusion criteria for the study were patients in age group of 18-45 years with chronic ACL deficiency while exclusion criteria were multi-ligamentous injury, any previous surgery in the same knee, arthritic changes (outbridge grade 4), focal grade III/IV chondral defects, malalignment and an abnormal contralateral knee. Patients were taken up for ACLR atleast 3 weeks after injury and only after they had regained at least 90 degrees range of movement with minimal swelling.

**Operative procedure**

All patients were operated under spinal anesthesia. Examination under anesthesia was done prior to the commencement of surgical procedure and tourniquet was used in all cases. A diagnostic arthroscopy was performed with the standard anterolateral (AL) and anteromedial (AM) portals and the tear of ACL was confirmed and concomitant meniscal injuries were managed. The AL portal was made first followed by AM portal. Accessory anteromedial (AAM) portal was created after reaming of the tibial tunnels. Semitendinous and gracilis tendon were harvested using a vertical 3 cm incision on the AM aspect of the upper tibia and stripped of muscle fibres. The semitendinosus (for the AM bundle) was doubled and gracilis tendon (for the PL bundle) was tripled. The ends of tendon were stitched with an ethibond (Ethicon, Johnson and Johnson) No. 5 suture using a whip stitch technique and the grafts were pretensioned on a graft board. The prepared average doubled semitendinosus tendon graft for the AM bundle were 7 mm in diameter and prepared tripled gracilis tendon for the PL bundle were 6 mm in diameter.

The soft-tissue remnants of the ACL were identified on the tibia and the femur as a guide for the insertion sites of AM and PL bundles. The tibial and femoral footprints of both AM and PL bundles were carefully defined and marked with the thermal device (Arthrocare, Sunnyvale, CA). When the remnants of the ACL were not visualized, the bony landmarks (lateral intercondylar ridge and lateral bifurcate ridge) were visualized to delineate the attachment on the femoral side. Tibial guide (Arthrex, Naples, FL, USA) was used for making the tibial tunnels. The AM tibial tunnel was drilled first zig set at 55° in the middle part of AM bundle footprint with the knee at 90°. The PL tibial tunnel was drilled next with zig set at 65° about 1 cm PL to AM tibial tunnel at the stump of PL bundle [Figure 1]. AM tibial tunnel followed by PL tibial tunnel were then reamed according to the graft size of each bundle. Both tunnels were blocked with a tunnel blocker to prevent water outflow. The AM femoral tunnel was drilled next using the trans-tibial approach with the knee in 90° flexion. The tunnel was drilled at the previous AM femoral footprint leaving at least 2 mm of posterior wall intact [Figure 2]. The length of the AM femoral tunnel was kept at 35 mm. The PL femoral tunnel entry point was made with knee in 90° flexion, at PL footprint with a drill bit via AAM portal; it was then withdrawn to the starting point. Then knee was hyper flexed, drill bit was advanced and brought out through the skin. PL femoral tunnel was subsequently reamed according to graft size up to 30 mm with a cannulated reamer and subsequently extended to the lateral femoral cortex with the 4.0 mm cannulated reamer [Figure 3].

Figure 1: Arthroscopic view showing 2.4 mm drill bits at the footprints of the two tibial anterior cruciate ligament bundles
The gracilis graft for the PL bundle was then rail-roaded through the AAM portal into the femoral tunnel and fixed at the femoral side using a Biointerference screw in all cases.

AM bundle graft is then fixed on the femoral side using crosspin femoral instrumentation using a 5 mm Transfix. The knee is then cycled several times through the range of motion and the PL graft is fixed at 0-15° of knee flexion whereas AM graft is fixed at 45° of knee flexion using biointerference screw [Figure 4]. The graft is assessed for any impingement and if present, notchplasty was done. Postoperative radiographs were taken on the 1st postoperative day [Figure 5].

Ice packs and static quadriceps exercises along with ankle pumps were started on the day of surgery. Patients were allowed weight bearing within the limits of pain with the help of crutches from the 1st postoperative day. A long-leg knee extension immobilizer was kept for the next 2 weeks. Closed chain exercises of the knee were started from the 1st postoperative day. The goal of rehabilitation was was to achieve 90° knee flexion and full extension by 4 weeks and full range of motion by the end of 12 weeks. The hamstring strengthening exercises were initiated after the end of week 4. Light jogging was allowed after 3 months. Patients were allowed to return to sports after 6 months.

Patients were followed up regularly and the functional outcomes were assessed 1 year postoperatively using the Lysholm Knee score, IKDC knee score, side to side difference in anterior laxity using KT-1000 arthrometer (MEDMetric, San Diego, USA) using anterior drawer force of 30 lb, manual pivot shift test and isokinetic muscle testing (HUMAC/NORM).

Paired t-test with the $P$ value set at 0.001 for KT 1000 measurements and Lysholm scores were used for statistical evaluation.
RESULTS

There were 64 males and 36 females in our study. Right side was involved in 72 cases and left in 28 cases. 52% of patients sustained injury during sporting activities while 38% sustained injury secondary to road traffic accidents, rest 10% sustained injury due to other causes. Most of our patients were active young adults with a mean age of 33.1 years (range 18-45 years) [Table 1]. Using the KT-1000 arthrometer, mean side to side difference of anterior translation with 134N improved from 5.1 mm ± 1.5 to 1.6 mm ± 1.2 (P < 0.001). At the final evaluation functional results were based on the IKDC criteria. 54% of the patients were in Category A and 36% in Category B [Table 2].

The mean postoperative Lysholm score was 89.1 ± 3.2 (range 67-100) [Table 2]. The score showed significant improvement from the preoperative score of 52.4 ± 15.2 (range: 32-76) (P < 0.001). 88 patients gained full range of motion after 3 months. 12 patients had a loss of terminal flexion, whereas none had loss of extension. At 1 year followup 96 patients had regained full range of movement; the rest four had terminal loss of flexion less than 10°. Out of these, 3 patients were Class III activity level persons who did not have any high physical demands. The quadriceps strength on isokinetic muscle testing had an average deficit of 10.3% while Hamstring had a 5.2% deficit at the end of 1 year as compared to the normal side, both being considered normal.

Partial medial meniscectomy was done in 21 cases and partial lateral meniscectomy in 15 cases. Initial posterior wall blowouts in AM femoral tunnels were seen in 4 patients and confluence in the initial intraarticular part of the femoral tunnels was seen in 6 patients intraoperatively. In none of the patients, confluence was more than 6 mm. None required change of fixation method.

AM femoral tunnel was made by trans tibial approach and was usually made at 11/10.30 O’clock position occupying major part of AM footprint, but not exactly the center. The PL femoral tunnel, which was made by trans portal approach through AAM portal was made in the center of PL footprint.

3 patients had stitch abscess while 1 patient had synovitis postoperatively. These were managed conservatively.

DISCUSSION

ACLR has advanced in the last few decades in terms of operative technology, graft options, fixation techniques and devices. There has been a transition from SBACL reconstruction to DBACL reconstruction, though controversy remains on advantages of DBACL reconstruction over SBACL reconstruction. 8,10,11,20,21 The basis of this transition is a better understanding of the anatomy of the ACL. It is now proven in various studies that ACL has two distinct bundles from the fetal stage - AM and PL. 22 The AM bundle primarily controls antero-posterior stability and the PL bundle primarily functions to controls the rotational stability. The goal of ACL surgery is to restore the normal tension pattern of each bundle as each bundle of ACL is at different tension levels at various flexion angles of the knee. Sakane et al. 23 investigated the specific role of each bundle for anterior-posterior stability and showed that the AM bundle has relatively constant level of in situ forces during knee flexion, whereas the PL bundle is more variable with high in situ forces between 0 and 30° of flexion but rapidly decreasing thereafter. Gabriel et al. 24 showed that the PL bundle contributes more to rotational stability of the knee in 15-30° of flexion.

One of the most significant factors that affect the clinical outcome of DBACL is the surgical technique. 25 In our technique, we drill the AM tibial tunnel at 55° first and then the PL tibial tunnel at 65°, which decreases the risk of confluence of tibial tunnels. The femoral tunnels were drilled on the respective stumps of AM and PL bundle. Drilling of AM bundle femoral tunnel in 90° flexion and PL bundle in knee hyperflexion was able to create divergence.

Table 1: Demographic and physical characteristics of the study group

| Age (years)          | 33.1 (18-45) |
|----------------------|--------------|
| Gender (M/F)         | 64/36        |
| Injured side (R/L)   | 72/28        |
| Mechanism of injury  |              |
| Sports               | 58           |
| RTA                  | 32           |
| Others               | 10           |
| Time between injury and reconstruction | Average 55.2 days (range 21 days-2 years) |
| RTA=Road traffic accident |

Table 2: Functional results after treatment

| Lysholm score (points)* | Preoperation 52.4±15.2 (32-76) | Postoperation 89.1±3.2 (67-100) |
|-------------------------|---------------------------------|----------------------------------|
| Full range of motion    | 96/100                          |
| Loss of motion-extension| 0/100                           |
| Loss of motion-flexion  | 4/100                           |
| Anterior translation side to side difference (KT-1000 arthrometer, 134N)* | Preoperatively (mm) 5.1±1.5 | Postoperatively (mm) 1.6±1.2 |
| IKDC activity levels    | Preoperative | Postoperative |
| A                       | 0 | 54 |
| B                       | 0 | 36 |
| C                       | 16 | 9 |
| D                       | 84 | 1 |

*Statistically significant (P<0.001), IKDC=International knee documentation Committee.
of tunnels. Use of biointerference screw for PL bundle and transfix (crosspin) fixation for the AM bundle combines the advantage of these two methods of fixation.

DBACL reconstruction is technically demanding due to the creation of 2 different femoral tunnels. There is a possibility of confluence of tunnels and posterior blowout of AM tunnel which makes the choice of fixation device and technique of tunnel drilling important. The combination should be able to overcome these complications while giving good graft pull out strength and least tunnel dilatation.

van Eck et al. in a systemic review of 74 studies on DBACL found that for femoral fixation Endobutton was used in 63.5% cases, biointerference screw in 12.2% cases while crosspin was used in only 1.4% cases. Cortical suspensory fixation/endobutton on the femoral side, overcomes problem associated with the confluence of tunnel. However, it carries the risk of significant tunnel widening later on. Biointerference screw causes least tunnel widening. Tunnel widening has not been shown to affect clinical outcome but can cause technical difficulty in revision surgeries.

Interference screw have the advantage of aperture fixation and least tunnel widening but have less pull out strength as compared to transfemoral crosspin.

Transfemoral crosspin fixation provides most rigid fixation but causes tunnel widening though it may be less as compared to cortical suspensory fixation as it is more near to the joint line. In our series, there was initial posterior wall blowout in 4 cases. Drilling of AM femoral tunnel in 90° flexion results in a tunnel which goes away from the posterior cortex as it moves away from the joint line. Therefore, even if posterior blowout occurs it doesn’t extend beyond initial part of the tunnel. All such cases were fixed with Transfix only as it fixes the graft 25 mm away from joint line and therefore is not affected by initial posterior AM tunnel blowout.

The most essential step in anatomic double-bundle ACLR is to create four independent tunnels at the center of the 4 anatomic attachments of the AM and PL bundles. Fixation of the AM bundle with transfix and biointerference screw and PL bundle with two biointerference screw is a surgeon friendly technique, which not only allows a stable and rigid fixation, but also leads to less tunnel dilatation later on as compared to other modes of fixation like cortical suspensory fixation (endobutton). This technique is also likely to be useful for surgeons who are using crosspin fixation for SBACL reconstruction and are learning to do DBACL reconstruction.

Confluence of tunnels especially on the femoral side can lead to compromised fixation. Though we were not able to find any study on the incidence of confluence of tunnels in DBACL reconstruction, we believe that the popularity of cortical suspensory fixation devices is due to the fact that it overcomes concerns of loss of fixation due to confluence of the tunnels. In our series, there was intraarticular confluence of tunnels in 6 cases only that too in the initial part with maximum confluence distance of 6 mm only. Drilling of AM bundle tunnel in 90° flexion and PL bundle in knee hyperflexion results in divergence of tunnels, therefore even if confluence of tunnel occurs it doesn’t go beyond initial part of the tunnel.

We created the AM bundle by transtibial method which didn’t allow us to make the tunnel in the center of AM footprint, though we were able to occupy the majority of AM footprint. Yasuda et al. in a study comparing SBACL, nonanatomical DBACL and anatomical DBACL reconstruction did not find any statistically significant difference between nonanatomical and anatomical DBACL reconstruction in terms of postoperative side to side anterior laxity, ROM, pivot shift and IKDC scores.

There was a significant difference in anterior tibial translation as measured with the KT-1000 postoperatively as compared with preoperative measurement after DBACL reconstruction. Manual pivot shift test was positive in only 6 cases, which indicate that most of the knees were stable. There was a significant improvement in Lysholm score at 1 year followup from 52.4 + 15.2 (r32-76) preoperatively to a postoperative score of 89.1 ± 3.2 (range 67-100) indicating good clinical outcome. As per IKDC criteria 54% cases were in category A and 36% in category B.

Siebold et al. while comparing SBACL and DBACL reconstruction using Endobutton CL on the femoral side and biodegradable interference screw on tibial side reported average KT-1000 side to side difference of 1.0 mm, objective IKDC was 78% “A” and 19% “B,” pivot shift test was negative in 97% cases and average Lysholm score was 90 at 19 months followup for DBACL reconstruction.

Jarvela et al. used bioabsorbable screw for both femoral and tibial side fixation and compared results of SBACL and DBACL reconstruction. In DBACL reconstruction group postoperative mean KT 1000 side to side difference was 1.3, IKDC score was A in 17/32 and B in 13/32 cases, Pivot shift was A in 26/32 cases and B in 6/32 cases and mean Lysholm score was 91.

Muscular strength was also evaluated using the isokinetic machine at 12 and 24 weeks. According to the study by Reardon et al., postoperative quadriceps atrophy occurs secondary to pain postoperatively. During the
later stages of rehabilitation, the difference of the peak torque between injured and the noninjured sides should be maintained at less than 10%. Following an ACL injury or ACLR, full recovery of quadriceps and hamstring muscle strength (Torque generating capacity) is not always achieved.33 In assessing and monitoring these strength deficits, many clinicians and researchers have implemented isokinetic dynamometry protocols. The above results for quadriceps weakness can be explained due to relative inactivity and an effective strengthening exercises following surgery, which leads type II muscle fiber atrophy.34 Furthermore, patients with ACLR demonstrate arthropgenic quadriceps inhibition in order to minimize anterior tibial translation and ACL graft strain.35 In contrast to the quadriceps, the hamstrings are less susceptible to strength deficits following an ACL injury. The strong rigid fixation of the two tunnels of both the femoral and tibial side allows for aggressive rehabilitation program.

There were certain limitations of our study. We had no comparison group of femoral fixation with cortical suspensory fixation device. Followup of patients was limited to 1 year only, though our emphasis was more on the use of alternative femoral fixation device, different from most commonly used cortical suspensory fixation. Furthermore, since femoral AM bundle was made by transtibial technique it was not always possible to create the tunnel at the center of original AM footprint, which might have resulted in nonanatomic AM bundle. Since no postoperative computed tomography/magnetic resonance imaging assessment was done therefore we cannot comment conclusively on the same.

To conclude, double bundle ACLR with femoral fixation using transfix for AM bundle and biointerference screw for PL bundle had significant improvement in KT 1000, Lysholm and IKDC scores at 1 year followup.

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