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Original Article

Analysis of modified double-bundle anterior cruciate ligament reconstruction with implantless fixation on tibial side

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ABSTRACT

Purpose: To avoid potential problems of double-bundle anterior cruciate ligament reconstruction (ACLR), various modifications have been reported. This study analyzed a novel technique of modified double-bundle (MDB) ACLR without implant on tibial side in comparison to single-bundle (SB) ACLR.

Methods: Eighty cases of isolated anterior cruciate ligament tear (40 each in SB group or MDB group) were included. SB ACLR was performed by outside in technique with quadrupled hamstring graft fixed with interference screws. In MDB group, ACLR harvested tendons were looped over each other at the center and free ends whipstitched. Femoral tunnel was created by outside in technique. Anteromedial tibial tunnel was created with tibial guide at 55°. The anatomic posterolateral aiming guide (Smith-Nephew) was used to create posterolateral tunnel. With the help of shuttle sutures, the free end of gracillis was passed through posterolateral tunnel to femoral tunnel followed by semitendinosus graft through anteromedial tunnel to femoral tunnel. On tibial side the graft was looped over bone-bridge between external apertures of anteromedial and posterolateral tunnel. Graft was fixed with interference screw on femoral side in 10° knee flexion. International Knee Documentation Committee (IKDC), Tegner score, Pivot shift and knee laxity test (KLT, Karl-Storz) were recorded pre- and post-surgery. At one year magnetic resonance imaging (MRI) was done. Statistical analysis was done by SPSS software.

Results: Mean preoperative KLT reading of (10.00 ± 1.17) mm in MDB group improved to (4.10 ± 0.56) mm and in SB group it improved from (10.00 ± 0.91) mm to (4.80 ± 0.46) mm. The mean preoperative IKDC score in MDB group improved from (49.49 ± 8.00) to (92.5 ± 1.5) at one year and that in SB group improved from (52.5 ± 6.9) to (88.4 ± 2.6). At one-year 92.5% cases in MDB group achieved their preinjury Tegner activity level as compared to 60% in SB group. The improvement in IKDC, KLT and Tegner scale of MDB group was superior to SB group. MRI confirmed graft integrity at one year and clinically at 2 years.

Conclusion: MDB ACLR has shown better outcome than SB ACLR. It is a simple technique that does not require fixation on tibial side and resultant graft is close to native ACL.

Introduction

Arthroscopic anterior cruciate ligament reconstruction (ACLR) is a major area of research worldwide. Double-bundle (DB) ACLR has been shown to be superior to conventional single-bundle (SB) technique, as both bundles act in synergistic way in response to anterior tibial and combined rotatory loads.[1] Anteromedial bundle is taut through out range of motion of the knee as anteromedial femoral foot print is the most isometric point on femoral side but posterolateral bundle is taut in extension and relaxed in flexion.

Though superior to SB ACLR, DB ACLR has potential risks of tunnel confluence, slippage of small diameter graft and overstuffing of notch especially in small knees. There could be osteonecrosis of the lateral femoral condyle and difficult revision surgery.[2]

To get advantage of DB construct that is having different tension pattern in fibers at different arc of motion of the knee but obviates potential difficulties of the double bundle technique, various modifications have been reported. These modifications are single tibial double femoral tunnel construct,[3] single tunnel double bundle construct,[4] single femoral double tibial tunnels with

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hamstring graft,[5,6] single femoral double tibial tunnels with quadriceps graft[7,8] and single femoral single branched tibial tunnel with hamstring graft.[9] Authors with all of these modifications have documented satisfactory results. Papachristou et al.[5] reported ACL reconstruction with hamstring graft, creating double tibial tunnel and single femoral tunnel, which they called delta plasty.[10] They reported excellent results with this technique in clinical as well as experimental settings. But this technique was not compared to SB ACLR in any of these studies, which is still most popular technique.

The fact that native ACL is broader at tibial insertion and narrower at femoral insertion forms the anatomic basis for such ACL graft construct.[11,12] Li et al.[13] in cadaveric study documented significantly better rotational stability in reverse “Y” plasty ACLR at varying degrees of knee flexion in comparison to SB ACLR. There is a paucity of literature comparing this graft construct (single femoral double tibial tunnels) with SB ACLR in clinical setting.

This study analyzed modified DB ACLR (single femoral double tibial tunnels) using autogenous free hamstring graft, without implant on tibial side in comparison to SB ACLR in clinical setting. This is the first study to compare results of modified DB ACLR with SB ACLR in clinical setting to the best of our knowledge. We aim to clarify whether the clinical outcome of modified DB ACLR is better than SB ACLR.

Methods

This prospective study was conducted after institutional approval. There were 80 subjects (40 cases in each group) of isolated anterior cruciate ligament tear with the age ranging from 18 to 50 years. ACL tear with associated other ligament injuries, cartilage lesions and intra-articular fractures and meniscal tear were excluded. All cases were enrolled consecutively between September 2016 and September 2017. The same surgical team operated all cases. Surgeons not involved in the surgery did the scoring.

Technique of modified DB ACLR

After surgical preparation, semitendinosus and gracillis were harvested through a longitudinal split in aponeurosis of Sartorius along the long axis of hamstrings.

Muscle tissue was cleared from each tendon in a standard way. The tendons were doubled over each other at the center of length of each tendon. Free tails of each tendon were whipstitched (Fig. 1). The diameter of graft (doubled semitendinosus, doubled gracills & quadrupled graft) was measured. The length of prepared graft was also measured. If the composite graft length is short, a fiber tape loop can be used to increase the length of graft by passing through the individual loop of graft.

Standard anteromedial and anterolateral portals are set up. Arthroscopic clearing of joint was done but remnant footprints were preserved as much as possible. With the knee placed in 90° of flexion, outside in ACL femoral guide was placed over femoral footprint of ACL. Starting at the flare of the femoral metaphysis, the guide pin was drilled from outside to inside and its intra-articular exit at anatomical femoral footprint is confirmed. The femoral guide was removed. A 2-cm incision was made at the entry point of pin over lateral aspect of the thigh and sequential reaming was done over the pin with the appropriate size reamer to match the diameter of quadrupled hamstrings. A sleeve was placed in femoral tunnel and stationed there.

Standard tibial guide set at 55° was placed over anteromedial tibial footprint and the intra-articular exit of guide wire at anteromedial footprint was confirmed. Tibial anteromedial tunnel was reamed according to the size of doubled semitendinosus graft. The anteromedial bullet of the size of anteromedial tibial tunnel was attached to anatomic posterolateral aiming tibial guide (Smith-Nephew). The anteromedial bullet is now inserted in anteromedial tunnel. A guide wire was passed through posterolateral sleeve of the anatomic posterolateral aiming tibial guide. The intra-articular position of guide wire through posterolateral tibial footprint was confirmed (Fig. 2). The posterolateral tunnel was drilled according to the size of doubled gracillis.

A non-absorbable suture loop was passed through the femoral tunnel from outside and retrieved into the joint through anteromedial portal. A suture retriever was passed through posterolateral tibial tunnel and suture loop in the joint was retrieved through exterior aperture of posterolateral tibial tunnel. Similar process was repeated with another suture loop that was passed from external aperture of femoral tunnel through anteromedial tibial tunnel to exterior (Fig. 3A).

The suture tail of sutured free end of gracillis was passed through suture loop shuttle coming out of posterolateral tibial tunnel. The suture tail of sutured semitendinosus was passed through suture loop shuttle coming out of anteromedial tibial tunnel. Both shuttle sutures were pulled one by one out of femoral tunnel to exterior to deliver free tails of sutured semitendinosus and gracillis. The posterolateral bundle was seated first by pulling its sutured end (Fig. 3B) followed by anteromedial bundle in similar fashion. Because posterolateral tibial tunnel is smaller in diameter than doubled semitendinosus graft, the semitendinosus side of graft acts as a natural stop to it being pulled up in posterolateral tunnel. Part of doubled semitendinosus forms a bridge between external tibial apertures of anteromedial and posterolateral tibial tunnels (Fig. 3C). Because the doubled semitendinosus is longer than doubled gracillis, the chances of graft being short on anteromedial side are less.

After graft was firmly seated, cycling was performed. The graft was fixed on femoral side by bioresorbable interference screw by outside in technique at 10° of flexion of the knee (Fig. 3D). Intra-articular graft is checked (Fig. 4).

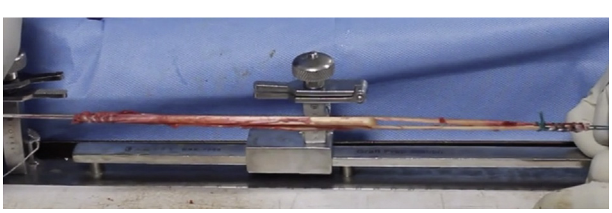

Fig. 1. Semitendinosus and gracillis looped over each other and free ends are whipstitched.

Fig. 2. Distance between anteromedial and posterolateral guide pins on tibial foot print of anterior cruciate ligament.

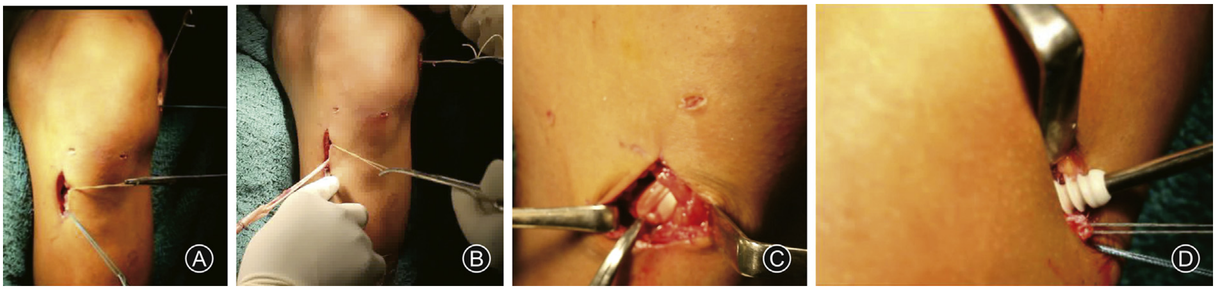

Fig. 3. (A) Shuttle sutures are passed through anteromedial and posterolateral tunnels from tibia to femur. (B) Posterolateral graft is seated first. (C) Graft seating on bone-bridge between anteromedial and posterolateral external aperture on tibia. (D) Interference screw fixation by outside in technique on femoral side.

After thorough lavage of joint, the wound was closed and dressing was done.

Technique of CB ACLR

The free autogenous hamstring harvest was similar to MDB but prepared in a 4-tail graft and dimensions were measured. Femoral tunnel was prepared as in MDB group. The tibial guide set at 50° was placed at the center of tibial foot print and guide wire passed. The tunnel was created as per size of graft. Graft passage and femoral side fixation was done similar to MDB group. After femoral side fixation, cycling was done, and then tibial side fixation was done with bioresorbable interference screw in 25° flexion of the knee.

Knee was immobilized in full extension with a knee brace. Routine analgesics and antibiotics were given during postoperative period.

Standard accelerated rehab protocol was instituted. Full weight bearing was encouraged as soon as possible. Routine follow-up was done at 2 weeks, 6 weeks, 3 months and 12 months. After 12 months, follow-up was continued to detect any subjective or objective instability of the knee.

Measurement of outcome

For functional outcome, International Knee Documentation Committee (IKDC) score and Tegner activity level were measured preoperatively and at one-year follow-up. Objective measurement of anterior tibial translation was performed preoperatively and at one-year follow-up by a knee laxity tester (KLT, Karl-Storz model No.28729). Manual Pivot shift test was also performed. At one-year follow-up, magnetic resonance imaging (MRI) was done to check for graft integrity. Statistical analysis was done with SPSS software version 13 (SPSS Inc USA). At two-years follow-up, subjective or objective instability if any was noted.

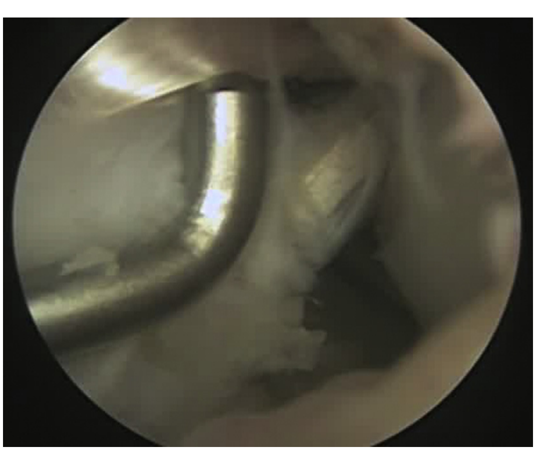

Fig. 4. Final intra-articular graft construct.

Results

There were 40 cases in each group, the age ranging from 18 to 50 years with a mean of (26.82 ± 7.53) years in MDB group and (27.65 ± 7.89) years in SB group. All were males in MDB group and 11 cases (27.5%) were females in SB group. Mean follow-up was (28.97 ± 3.37) months for MDB group and (29.22 ± 3.60) months for SB group.

The mode of injury was variable. Nineteen cases in MDB group and 17 cases in SB group had fall from bike; 15 cases in MDB group and 7 cases in SB group had injury during sports; 4 cases in MDB group and 8 cases in SB group had fall on ground; 2 cases in each group had fall from height and 6 cases in SB group had fall at stairs.

Out of the 40 cases, 5 cases in MDB group and 13 cases in SB group had mid substance tear, 35 cases in MDB group and 25 cases in SB group had tear at the femoral attachment of ACL and 2 cases in SB group had tear at tibial insertion. The mean time interval between injury and surgery was (16.08 ± 9.29) months in MDB group and (11.70 ± 16.33) months in SB group.

In MDB group the mean composite length of doubled semitendinosus and gracillis was (253.71 ± 14.01) mm. Twenty-three cases (57.5%) had graft length between 251 and 275 mm and 14 cases (35%) had graft length between 225 and 250 mm. It was more than 275 mm in one case (2.5%) and less than 225 mm in two cases (5%). The diameter of doubled semitendinosus (for AM bundle) was 6 mm in 24 cases (60%), 7 mm in 15 cases (37.5%) and 8 mm in one case (2.5%). The diameter of doubled gracillis (for PL bundle) was 5 mm in 24 cases (60%) and 6 mm in 14 cases (35%).

All cases in both groups could achieve stable knee. The mean preoperative KLT reading in MDB group was (10.00 ± 1.17) mm that improved to (4.1 ± 0.56) mm at follow-up. The mean preoperative KLT reading in SB group was (10.00 ± 0.91) mm that improved to (4.80 ± 0.46) mm. The magnitude of improvement in KLT reading was better in MDB group than SB group with statistical significance. Pivot shift test was negative in all cases of both groups till final follow-up.

The mean preoperative IKDC score in MDB group was (49.49 ± 8.00) and it improved to (92.5 ± 1.5) at one year. The mean preoperative IKDC score in SB group was (52.5 ± 6.9) and it improved to (88.4 ± 2.6) at one year.

Preoperative Tegner activity level in MDB group was level 4 in 8 cases, level 3 in 24 cases, level 2 in 7 cases and level 1 in 1 case. Postoperative Tegner activity level improved to level 8 in 9 cases, level 7 in 23 cases and level 6 in 8 cases.

Preoperative Tegner activity level in SB group was level 3 in 13 cases, level 2 in 20 cases and level 1 in 7 cases. Postoperative Tegner activity level improved to level 8 in 1 case, level 7 in 12 cases, level 6 in 18 cases and level 5 in 9 cases.

At six-months follow-up 29 cases in MDB group and 21 cases in SB group could return to preinjury Tegner activity level. At one-year 37 (92.5%) cases in MDB group achieved their pre-injury Tegner activity level as compared to 26 (60%) in SB group.

At one-year follow-up graft was found intact in all cases of both groups on MRI (Fig. 5). Even after two years there was no instability till final follow-up in both groups.

Discussion

Stability was achieved in all cases in both groups after ACLR. Objective measurements of anterior tibial translation showed significant improvement in both groups at follow-up in comparison to preoperative status. Though none of the case in either group had complaint of subjective instability in postoperative period, the objective improvement of anterior tibial translation (ATT) in MDB group was better than SB group and was statistically significant ($p < 0.001$). Objective measurement of ATT is strength in this study as the results of previously reported studies were based only on subjective scoring in clinical setting and ATT could only be measured at time zero in lab setting. Wider foot print of ACL insertion provides better stability, which is a case with MDB technique as it provides wide footprint on tibia. The advantage is depicted by significantly better ATT in MDB group as compared to SB group. The Pivot shift test was negative in both groups but it is difficult to appreciate minor difference in pivot shift in a wake patient in clinic. It has been established by cadaveric studies that the native ACL has a bigger tibial footprint than femoral foot print.[14,15] In cadaveric study Iriuchishima et al.[14] reported that tibial foot print of ACL (133.8 ± 31.3) mm is nearly twice the size of femoral foot print (69.8 ± 25.0) mm.

There was statistically significant improvement in postoperative IKDC and Tegner activity scores in both groups as compared to preoperative status. But improvement of IKDC score in MDB group was significantly better than SB group ($p < 0.001$). Return to pre-injury status, it was better in MDB group in comparison to SB group as depicted by better Tegner scale.

Though authors of previous studies have reported satisfactory outcome with this technique, there was no control group for comparison to modified DB ACLR in clinical setting.[5–9]

Fig. 5. Follow-up magnetic resonance imaging showing two distinct low signal bundles of anterior cruciate ligament.

Papachristou et al.[5] used suspensory fixation on both sides but we used interference fixation on femoral side and implant less suspensory fixation on tibial side in form of graft loop over bone bridge on tibia. Sacramento et al.[16] have also reported implant less fixation over tibial bone bridge in DB ACLR. They have tied the free suture ends of graft in anteromedial and posterolateral tunnel over bone bridge in 20° knee flexion.

Tibial fixation site is a potential weak link in ACLR with the risk of graft slippage in early postoperative period. Though there was no case of tibial fixation side failure in either group, we feel that looped graft over tibial bone bridge (between anteromedial and posterolateral tunnel) at external aperture in MDB group is more secure. The looped construct of graft over bone bridge in tibia also provides advantage of implantless fixation as well as eliminates chances of graft pulling-out from tibia in rehabilitation period. If the harvested graft is small that can happen with gracillis, it can be lengthened using an extension loop of fibre wire. This loop remains outside the tunnel over the bone bridge of the tibia. But in this study graft length was not a problem and extension loop was not required in any case in MDB group.

Papachristou et al.[5] reported better load to failure strength with this technique than SB ACLR in porcine model. They also reported better load to failure strength with suture after fixation than suture button fixation in biomechanical setting. But we have used bioresorbable interference screw fixation on femoral side without any case of failure on femoral side in either group. One of the strength of MDB technique is that all the tunnels are occupied with graft giving more graft bone contact surface area for better healing.

Most studies recommend fixation of posterolateral bundle in 10°–20° of flexion and that of anteromedial bundle in 70°–90° flexion[6] including Papachristou et al.[5] Park et al.[7] fixed posterolateral bundle at full extension and anteromedial bundle at 45° flexion. Fixation of both bundles was performed in knee flexion of 20° by Naser,[9] 30° by Yasuda et al.[17] and 20° by Sacramento et al.[16] We fixed both bundles in 10° of knee flexion. It was based on the fact that anteromedial bundle is more isometric than posterolateral bundle making it taut in whole flexion range but posterolateral bundle is taut in only first 30° knee flexion. One of the advantages of reported technique over other implantless tibial fixation techniques is no risk of loss of tension in graft while fixing it as interference fixation is done at the same time when assistant holds the graft in tension.

One of the advantages of MDB ACLR over SB ACLR is there is no tibial fixation required that minimizes the hardware and cost of the procedure.

There was no complication in MDB and SB groups. The only drawback of MDB over SB group was increased tourniquet time.

Weakness of the study is non-randomized case recruitment.

In conclusion, the MDB ACLR has shown significantly better short-term clinical outcome as compared to the SB ACLR. The graft construct is close to native ACL. It is a simple and reproducible technique that does not require fixation on tibial side and thus minimizes the cost.

Funding

Nil.

Ethical Statement

This prospective study was conducted after institutional approval.

Declaration of Competing Interest

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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