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FEMORAL INTERFERENCE SCREW DIVERGENCE IN ANTERIOR CRUCIATE LIGAMENT (ACL) RECONSTRUCTION

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Abstract

Introduction: The interference screw is used to rigidly fix bone-patellar tendon-bone (B-PT-B) graft in anterior cruciate ligament (ACL) reconstruction. We hypothesized that interference screw placement through the patellar tendon (PT) portal (through donor defect) in a transtibially drilled femoral tunnel could be less divergent. We investigated the difference in divergence of interference screw placed through the PT portal and anteromedial (AM) portal and its clinical relevance.

Materials and Methods: In this prospective study, twelve patients underwent femoral tunnel B-PT-B graft fixation through AM portal (group 1) and the other 12 (group 2) through the PT portal. Femoral tunnel-interference screw divergence was measured on postoperative digital lateral X-rays. Ha's method was used to grade divergence. The clinical outcome was assessed by postoperative intervention knee documentation committee grading (IKDC) and Lysholm score at two years of follow-up.

Results: Mean tunnel-screw divergence in sagittal plane through AM portal was 13.38^{o} and through PT portal was 7.20^{o} ($P<0.0001$). In the AM portal group, 82.9% of patients had divergence in either grade 3 or 4 categories, whereas, in the PT portal group, 82.9% were in grade 1 or 2 categories ($P<0.0001$). Mean Lysholm scores were 92.8 and 94.5 at two-year follow-up in both groups ($P>0.05$). The International knee documentation committee grades of patients in both groups were similar.

Conclusion: Femoral interference screw placement through the PT portal leads to significantly less screw divergence than screw placement through the AM portal. However, this difference in divergence is not reflected in clinical outcomes.

Keywords: Anterior Cruciate Ligament; Bone Screw; Bone-Patellar Tendon-Bone; Reconstruction

1. INTRODUCTION

The knee joint is the most commonly injured of all joints, and the anterior cruciate ligament (ACL) is the most commonly injured ligament (1-3). The anterior cruciate ligament forms the pivot in the functional congruence and stability of the knee in association with other ligaments, capsules, muscles, and bone (4, 5).

Arthroscopic reconstruction of torn ACL has become the gold standard in treating ACL tears (6). The surgical reconstruction of the anterior cruciate ligament with Bone-Patellar Tendon-Bone (B-PT-B) autograft represents an attempt to re-establish knee kinematics and is a reliable method for ACL

reconstruction (7-9). It has the added advantage of bone-to-bone healing and does not sacrifice knee stabilizers (10). The Interference screw is a reliable and frequently used method for graft fixation (11-16). It also provides excellent fixation and pullout strength to the graft. Various factors affect the pullout strength of the graft, including bone block size, quality of bone, the gap between bone block and tunnel, screw diameter and length, and the angle between screw and bone block (parallel or divergent) (17-23). Biomechanical and clinical ramifications of a divergent interference screw in the bone tunnel (tibial or femoral) are now well established and are key factors in the success of the B-PT-B graft (17-19). The interference screw in a transtibially drilled femoral tunnel is commonly placed through the anteromedial (AM) portal or accessory AM portal over a guide wire. However, this is not in line with the transtibially drilled femoral tunnel and can lead to screw divergence. If the divergence is more than 15^{o} between interference screw and bone block, the pullout strength of the graft decreases sharply, affecting the graft-tunnel healing, pullout strength, and the clinical outcome (18, 19, 24-27). We hypothesized that interference screw placement through the patellar tendon (PT) portal (through donor defect) in a transtibially drilled femoral tunnel can be less divergent. The primary aim of this prospective randomized comparative study was to investigate whether an interference screw placed through the PT portal shows less divergence than a screw placed through the AM portal. The secondary aim was to examine the difference in the clinical outcome between the two modes of screw placement.

2. MATERIALS AND METHODS

In this prospective randomized comparative study, the femoral tunnel fixation was done in patients who were undergoing arthroscopic ACL reconstruction between May 2016 and May 2018 using B-PT-B graft by either of the following techniques. One is through AM portal (group 1) and the other through the PT portal – donor defect (group 2). Patients with no prior knee surgery and normal contralateral knee were included in the study. Written informed consent was obtained from the patients.

Under spinal or epidural anesthesia, the patient was put supine on the fracture table with the affected leg hanging and the other leg in the lithotomy position. The knee was examined for ligament injury using the Lachman test, anterior drawer test, pivot shift test, valgus and varus stress test, and posterior drawer test. After applying the tourniquet, the knee was extended over the leg holder. Parts were cleaned and draped, and a diagnostic arthroscopy was performed using standard anterolateral and anteromedial portals. The diagnosis of ACL tear confirmed arthroscopically and associated chondral lesions and meniscal tears diagnosed and treated. All patients underwent single-incision ACL reconstruction using a B-PT-B graft.

2.1. HARVESTING THE GRAFT:

The skin incision was made vertically from the inferior pole of the patella to the superior margin of the tibial tubercle. Skin flap raised to enable full visualization of the tendon width. The paratenon was dissected from the patellar tendon. The middle third of the patellar tendon measured approximately 10 mm and was harvested along with patellar and tibial bone plugs up to 25 mm long using the oscillating saw and removed with an osteotome. Just before separation, two drill holes are made in the bone plug.

2.2. GRAFT PREPARATION:

The bone plugs are trimmed to the desired width (8mm - 11 mm). The width was checked using appropriate sizer templates. The graft edges were smoothened, and sutures were passed through the drill holes.

2.3. NOTCHPLASTY:

It was done as a regular procedure. Graft impingement may lead to loss of terminal extension and ‘Cyclops lesion’ (large lump of scar-like material). Notchplasty was done using a specialized curette and automated shaver. Care is taken not to extend the notch too far

medially or superiorly as it may interfere with the patellofemoral articulation.

2.4. TIBIAL TUNNEL PLACEMENT:

The tibial tunnel is made using the 'TIBIAL JIG'. The angle of the guide is usually adjusted with the calculation 'N + 10', where N stands for the length of the patellar tendon. The tibial guide pin is drilled and brought through at the junction of the middle and posterior third of the normal ACL attachment. The tibial tunnel was prepared by serial drilling from 6 to 9 mm cannulated reamers over a guide wire exiting 6 mm anterior to the anterior fibers of the posterior cruciate ligament, just medial to medial tibial spine in the posterior footprint of torn ACL fibers. Care is taken not to form a vertical tunnel. The intra-articular edges of the tunnel are smoothened using the automated shaver.

Three reference points - the inner edge of the lateral meniscus, the base of the medial spine, and the posterior cruciate ligament - were used for the tibial guide wire. The tibial tunnel should be posterior to the roof of the altered intercondylar notch to prevent graft impingement in knee extension.

2.5. **FEMORAL TUNNEL PLACEMENT:**

With the knee at 80 to 90^{o} of flexion, the femoral tunnel was drilled over a guide wire which was kept 7 mm anterior to the posterior edge of the lateral femoral condyle at 10:30 'o'clock in the right knee and 1:30 ' o'clock in the left knee using a femoral offset of 6 mm. Bicortical drilling was done with a 4-mm cannulated reamer. Then, a 30 mm long femoral tunnel was drilled serially with 7- to 9-mm cannulated reamers. The posterior cortex is checked for any breach of the back wall.

2.6. GRAFT PASSAGE:

The sutures are passed through the eye of the Beath pin, and the proximal end of the pin is pulled to pass the graft through the tibial and femoral tunnel from the bottom to the top. The cancellous portion of the graft was facing anterolateral. Care is taken that no bone is allowed to protrude into the joint cavity at both the tibial and femoral ends. Tibial plug protrusion can be avoided by matching the graft length and osseous tunnels. Small discrepancies may sometimes still exist, requiring some adjustment. Shortening the bone plugs by 2 to 3 mm or deepening the tunnel by 3 to 5 mm can compensate for a small difference.

2.7. GRAFT FIXATION:

Knee was flexed to 110 ^{o,} and a guide wire advanced into the notched portion of the tunnel to minimize divergence through the selected portal, i.e., AM (group 1) or PT (group 2) portal (through the donor defect). To achieve graft fixation in the femoral tunnel, a titanium interference screw of appropriate length and diameter was inserted over the guide wire using the selected portal (according to randomization) into the femoral tunnel. Care is taken for the screw not to protrude into the articular area. Move the knee through a few cycles of motion to check for impingement.

Again, the guide wire was kept parallel to the graft in the tibial tunnel, and the graft was fixed with an interference screw keeping the knee at 30^{o} flexion with force-directed posteriorly onto the shin of the tibia. Interference screws are placed at the cancellous side of the bone plug in the tibial tunnel with the graft sutures pulled firmly under tension.

After the ACL reconstruction, Lachman and Pivot shift tests were performed to assess the adequacy of fixation.

2.8. WOUND CLOSURE:

After irrigation of the knee joint, the patellar tendon and paratenon were closed separately. The subcutaneous tissue and skin were closed over a drain in the knee joint. A compression bandage was applied and the limb immobilized in a long knee brace.

2.9. DIAGNOSTIC ARTHROSCOPY and GRAFT PASSAGE – PATELLAR TENDON PORTAL

Diagnostic arthroscopy and graft passage were performed on the patients (Figures 1, 2).

Figure 1 - PATIENT POSITIONING AND SURFACE MARKING

Figure 2 – GUIDE WIRE PLACE THROUGHTHE PATELLAR TENDON DEFECT.

2.10. POST-OP REHABILITATION

Rehabilitation was started on the day after surgery under the direct supervision of the surgeon. Drain removed at 24-48 hours. The knee was immobilized in a knee brace. The accelerated rehabilitation program is listed in Table 1.

Table 1 - The accelerated rehabilitation program

Time	Motion	Muscles Training
Phase - I Preoperative	Aim to prevent muscle atrophy Prepare patient for the	Good quadriceps setting. Heel slides/ SLR Normal gait pattern emphasized

	procedure	
Stage - II up to 2 weeks	Aim to decrease pain and swelling Starts on the day of surgery	Knee immobilized Quadriceps exercise Foot ankle pump
Stage III 2 - 6 weeks	Emphasis on increasing ROM Increasing weight-bearing	Brace continued Full weight-bearing No active flexion
Stage IV After 6 weeks	Aim to improve muscular control and proprioception	Closed chain Kinetic exercise Active knee flexion

2.11. EVALUATION

Postoperatively X rays (Standard Anteroposterior and Lateral views) were taken on the operated limb. The tunnel positioning and screw placement were documented. All patients were reviewed periodically at 6 weeks, 3 months, 6 months, and 1 year for assessment.

The patients were evaluated using the International Knee Documentation 2000 Score (IKDC) and Lysholm and Gilquist Knee Scoring Scale.

The IKDC 2000 Score is a single-page form consisting of a documentation section, a qualification section, and an evaluation section. The documentation section records the patient's details and the history of injury. The qualification is the major part of the IKDC form, and it consists of eight parameters for evaluation like effusion, range of motion, ligament function, compartment findings, harvest site pathology, radiographic finding, and functional testing. The three problem areas viz. effusions, range of motion, and ligament examination, are evaluated for group qualification. The worst qualification within the group gives the group qualification.

The final outcomes are documented as A, B, C, and D. 'A' being - Normal' functional outcome and 'B' as 'Nearly Normal' functional outcome. 'C' being 'Abnormal', and 'D' are 'Severely Abnormal' functional outcomes.

The Lysholm and Gilquist Knee Scoring Scale also comprised eight evaluation parameters. The parameters evaluated were - limp, use of support on walking, locking episodes, instability, pain, swelling, stair climbing, and squatting. The individual parameters were allotted specific scores depending on the patient's functional ability. The maximum possible knee score was 100 points. Based on the outcome scores, they were divided into Excellent (95-100 points), Good (84-94 points), Fair (65-83 points), and Poor (64 or fewer points).

3. RESULTS

All 24 patients were available for follow-up and were followed up every month during the first four months and every two months during the first year. The minimum follow-up was six months, and the maximum was 25 months, the mean follow-up being 15.75 months. Twelve patients underwent femoral tunnel fixation by titanium interference screw through AM portal (group 1) and the other 12 patients through the PT portal (group 2). There were 20 males and 4 females in this study with a mean age of 30.6 years. 14 patients had right-sided injuries, with sports injuries being the most common mode of injury. The majority of the 24 patients, i.e., 10 patients, had an interval of > 3 months to 6 months between the injury date and surgery. Knee pain was the most common symptom at presentation, followed by instability and locking of the knee joint. 12 patients out of our 24 patients had associated chondral lesions. 7 patients had chondral lesions at more than one site. The commonest site of the presentation was the medial femoral condyle. Meniscal injuries were present in 13 patients. Partial medial meniscectomy was done in 9 patients, and partial lateral meniscectomy was done in 4 patients (Figure 3, 4).

All the patients at the end of 1-year follow-up were functionally evaluated based on IKDC SCORE. Of the 24 patients, 15 had normal outcomes, 8 had nearly normal outcomes, and 1 had abnormal outcomes. Of the 15 normal outcomes, 6 patients belonged to group 1 (AM), and 9 belonged to group 2 (PT). Of the 8 nearly normal outcomes, 5 patients belonged to group 1 (AM),

and 3 belonged to group 2 (PT). One patient with an abnormal outcome belonged to group 1 (AM) and was attributed to a poor preoperative IKDC score. Of the patients taken up for the study, 15 had improved by one grade, and 9 had improved by two grades**.** We had 75% of patients in the AM portal group with screw divergence in either grade 3 or 4 categories, whereas 83.33 % were in grade 1 or 2 categories in the PT portal group. Chi-square test applied between the two groups was statistically significant (P<0.0001). The mean tunnel-screw divergence in sagittal plane through AM portal was 13.15^{o} and through PT portal through donor defect was 7.24^{o}

The Lysholm and Gillquist knee scoring scale was also used to evaluate the functional status of our patients. We had 15 patients with excellent outcomes, 7 with good outcomes, and 1 with a fair outcome. Of the 15 patients with excellent outcomes, 6 belong to group 1 (AM), and 9 belong to group 2 (PT). Of 8 patients with good outcomes, 5 patients belong to group 1 (AM), and 3 belong to group 2 (PT). The fair outcome belonged to group 1 (AM). Both groups had an average postoperative Lysholm score of 91.6 (group 1) and 95.4 (group 2).

We came across the following complications. Three patients had paresthesia over the anteromedial portion of the tibia, which settled subsequently. One patient had a screw back out from the tibial site at a one-year follow-up, and the screw was removed. However, his functional status was good. One patient had a superficial infection (stitch abscess), and it was controlled by oral antibiotics and dressing. One patient had a persistent restricted range of motion after ACL reconstruction for four months; he was treated by manipulation under general anesthesia to attain a functional range.

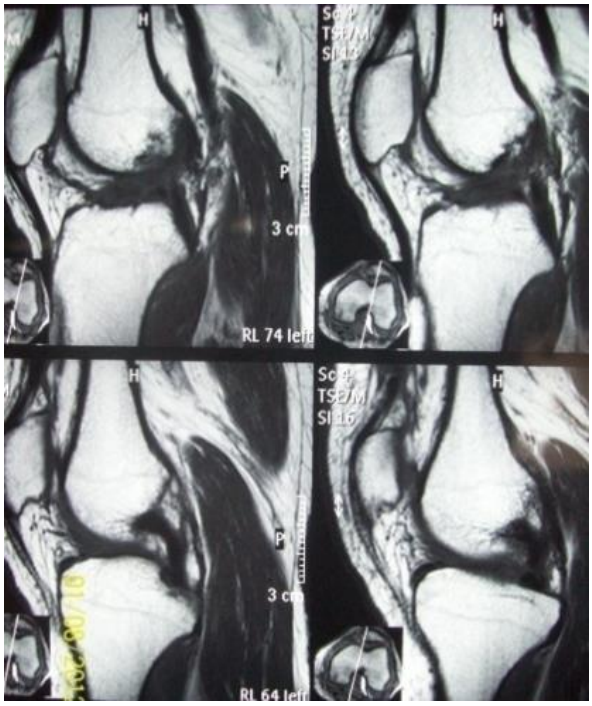

Figure 3 - Pre-op MRI of the right knee of CASE NO. 3 (PT portal)

Figure 4 - Pre-op (left) and post-op (right) x-rays of CASE NO. 10 (AM portal).

4. DISCUSSION

Over the past several decades, development in arthroscopic techniques and improvement in technology and research have allowed anterior cruciate reconstruction to become one of the most successful surgical techniques in sports medicine (1-3). The advantages of arthroscopically assisted ACL reconstruction are that there is a minimum injury to the synovial membrane of the joint, and yet it achieves the goals accomplished by the open operative technique. The theoretical advantage of arthroscopic surgery includes less injury to the patellofemoral mechanism and possibly less frequent symptoms and contractures of the patellofemoral joint post operatively. The proper site for the location of bone tunnels can be better identified by an arthroscope. In addition, the correct relationship of the graft with respect to the lateral wall of the intercondylar notch can be established (4-7). At present, the most commonly used grafts for ACL reconstructions are B-PT-B autograft and hamstring tendon grafts (2-5).

The central one-third of the B-PT-B graft was used because of its excellent biomechanical properties. It is the strongest of the immediately available substitute. The graft can be placed accurately during the surgery for it to act isometrically both in its location and tension. Bone to bone healing is more secure and rapid when compared to other grafts. It does not sacrifice the knee stabilizers. The B-PT-B graft is time-tested and has lesser complications and less significant morbidity. Fu et al. (28) and Ritchie (29) stated that B-PT-B autograft is the gold standard and the first choice in anterior cruciate ligament reconstruction. Also, the rigid fixation of the bone graft using interferential screws adds to the stiffness of the graft.

Feagin(16) was the first one to note that screw divergence can lead to loss of fixation strength. Screw divergence inside the femoral tunnel can lead to inappropriate fixation of bony graft and decreased pullout strength. Jomha et al. reported that pullout strength decreases with increasing divergence (0^o, 10^o, 20^o, and 30^o) in his study on 20 porcine knees. He reported that maximal fixation is observed at 10^o of divergence and decreases as angle increases.

In another model using 90 porcine knees and 5 human cadaveric knees, Fulkerson et al. (18)reported that divergence more than 30^o leads to loss of fixation and significantly decreased pullout strength.(25) Lemos et al. in a bovine model reported that divergence less than 15^o did not affect fixation characteristics. Though many authors have reported varying acceptable degrees of divergence, the surgical objective is always to place the screw in the femoral tunnel as parallel to the graft as possible.(20,21,27)

To our knowledge, there are no published studies in English literature comparing two methods of interference screw placement in femoral tunnel and divergence. Our results prove that acceptable levels of divergence can be achieved by using PT portal through donor defect with correct knee positioning. The mean divergence remained 7.2 ^{o} which is within normal limits of divergence and does not affect pullout strength of graft. The technique does not require the making of an additional portal (accessory AM portal) or special instrument. The fear of damaging infrapatellar fat pad by traversing interference screw seems to be exaggerated. While inserting the interference screw, no undue pressure should be applied as it can force the fat pad into the joint and can obscure the vision temporarily. Gentle screwing action is sufficient to negotiate the interference screw through fatpad. Divergence within 30^o is said to be acceptable as far as clinical result is concerned. However, the more in line PT portal through donor defect is much effective in reducing the divergence and keeps it to the minimum level. Also, to our knowledge, there are no published studies which compared the divergence of interference screw by different methods with respect to the clinical result in patients. In our study, the average postoperative Lysholm score were similar in both groups 97.14 and 98.02 (AM and PT portal, respectively), indicating that though there were radiological differences between both groups; there was no difference in clinical outcome. The IKDC objective grades were also similar in both groups, indicating that though there is angle difference between the two groups, it may not lead to any clinical difference as long as the divergence angle is within acceptable limits.Interference screw divergence in the

femoral tunnel can also lead to bending of intrafemoral tunnel portion of guide wire. If the guide wire bends, it becomes difficult to pull out the guide wire. In order to accomplish that, sometimes it might be necessary to remove the interference screw and reinsert, which weakens the interference fit. So, using an appropriate portal (PT) can minimize the guide wire bending as it avoids excess divergence. Rarely, divergence can also lead to cortical penetration causing blow out or graft fracture in femoral tunnel.
The limitation of this study is that only sagittal plane divergence has been evaluated. It is difficult to accurately outline the femoral tunnel in the coronal plane in the AP view of the x-ray. However, a randomized study with a larger sample size with long follow-up is desired to study the relation between multiplanar divergence (using computed tomography scan) and clinical outcome using these two portals.

5. CONCLUSION

Femoral interference screw placement through the PT defect provides significantly less screw divergence as compared with screw placement through the AM portal. The short-term results are encouraging, with minimal screw divergence with a good clinical outcome.

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