Preliminary Clinical Results of Two Techniques for Addressing Graft Tunnel Mismatch in Endoscopic Anterior Cruciate Ligament Reconstruction

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This study reports the initial clinical results of 540° of graft rotation or free tibial bone block to address graft tunnel mismatch in endoscopic anterior cruciate ligament (ACL) reconstruction. The operative reports of patients who underwent endoscopic ACL reconstruction between 1999 and 2001 were reviewed. Nine of 11 patients treated with a free tibial bone block and 14 of 17 patients treated with 540° of graft rotation were evaluated. Mean follow-up was 20 months (range: 13-40 months) for the bone block group and 34 months (range: 18-48 months) for the 540° group.

There were statistically significant improvements in physical examination test results postoperatively, and only one patient in the 540° group had a grade one positive pivot shift test. KT-1000 arthrometer testing demonstrated a statistically significant decrease in manual maximum and side-to-side differences at final follow-up. Mean Lysholm and Noyes sports function scores were excellent or good for all patients. One patient required reoperation for flexion contracture, one patient required an arthroscopic irrigation and debridement for a minor infection, and one patient required arthroscopic subtotal medial meniscectomy for failed meniscal repair. No difference was noted between these results and previous results of patients undergoing conventional endoscopic ACL reconstruction. These results demonstrate graft rotation and free bone block techniques are effective in addressing graft tunnel mismatch in endoscopic ACL reconstruction.

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INTRODUCTION

Clinical experience with an endoscopic technique for anterior cruciate ligament (ACL) reconstruction has identified graft tunnel mismatch as a potential problem (Figure 1).[21,22] Multiple techniques described to resolve this issue primarily use alternate methods of fixation. At the authors' institution, external rotation of the graft by 540° is used for limited mismatch problems and a free tibial bone block technique is used for larger construct mismatch. Biomechanical studies have demonstrated no difference in initial load to failure of a rotated graft compared to a graft fixed in neutral rotation.[25] Similarly, biomechanical studies have demonstrated the initial failure strength of a graft fixed with a free tibial bone block technique to be equivalent to conventional interference screw fixation.[18] However, only one study has reported limited clinical follow-up in patients treated with graft rotation, and no clinical follow-up has been reported in patients treated with a free bone block technique.[1]

This study reports the initial clinical results with graft tunnel mismatch treated with either external graft rotation of 540° or free tibial bone block.

MATERIALS AND METHODS

The operative reports of all patients who underwent endoscopic ACL reconstruction by the senior author (B.R.B.) between 1999 and 2001 were reviewed. A total of 246 patients underwent endoscopic ACL reconstruction during

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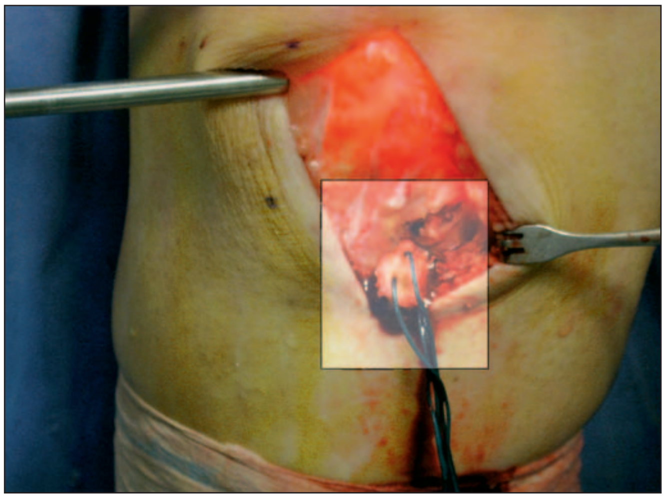


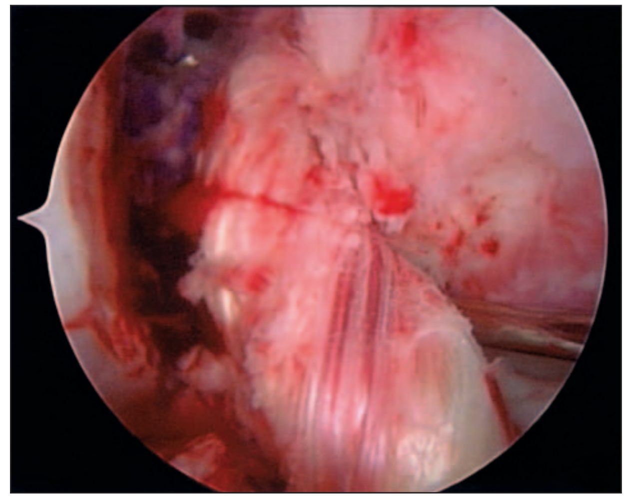


Figure 1. Intraoperative photograph demonstrating graft tunnel mismatch. The graft has been fixed on the femoral side using standard interference screw fixation. A significant portion of the tibial bone plug remains outside the tibial tunnel. **Figure 2.** Arthroscopic photograph demonstrating a graft that has been rotated 540° to achieve graft shortening. **Figure 3.** Intraoperative photograph demonstrating preparation of the free tibial bone block and soft-tissue construct with Krackow stitch.

the study period. Exclusion criteria were hamstring tendon autograft reconstruction, revision ACL reconstruction, multiligament reconstruction, combined posterolateral reconstruction, and combined high tibial osteotomy-ACL reconstruction. Of the patients identified with significant graft tunnel mismatch, 11 underwent ACL reconstruction with free tibial bone block and 17 underwent ACL reconstruction with 540° of graft rotation. Nine patients were available for follow-up in the bone block group, and 14 patients were available for follow-up in the 540° group. All patients were reexamined by an independent evaluator.

Surgical Technique

The surgical technique for endoscopic ACL reconstruction has been described previously.[9] Bone-patellar tendon-bone allograft or autograft were used for all reconstructions. Allografts were obtained from the middle third of whole patellar tendon grafts. In general, graft width was approximately 10 mm, and 25-mm bone plugs were used on either end. The tibial tunnel was drilled using an "N+10" rule to determine the angle of the tibial guide, with "N" representing the length of the soft-tissue portion of the graft. However, angles >60° were not used as this could have resulted in a vertical graft. Interference screw fixation was achieved with a 7×25-mm cannulated interference screw on the femoral side.

The tibial bone block normally was externally rotated 180° prior to fixation. If graft tunnel mismatch <12mm was identified, an additional 360° of rotation was performed for a total rotation of 540° (Figure 2). Measurements were made on the superior surface of the bone plug, at the 12-o'clock position of the tibial tunnel. Rotation was performed after securing the graft on the femoral side with an interference screw. Rotation was achieved using the sutures in the tibial bone plug or a straight hemostat. Interference screw fixation was achieved with a 9×20-mm screw, with the screw placed anteriorly along the cortical side of the bone plug.

If graft tunnel mismatch >12 to 15 mm was identified, a free tribial bone block technique was performed. Using a scalpel, the tendon was stripped off the bone plug. A Krackow or whip-type stitch then was run through the free tendon end using a no. 2 Ethibond suture (Figure 3). This effectively created a pseudo-quadriceps tendon graft. After the graft was secured on the femoral side using a standard interference screw technique, tension was maintained on the graft sutures while the free bone plug was placed in the tibial tunnel anterior to the soft tissue. A 9×25-mm interference screw then was placed along the cortical edge of the tibial bone plug (Figure 4). All grafts were secured with the knee in extension, and a tourniquet was not routinely used during the surgical procedure.

Postoperative Rehabilitation

A standard accelerated postoperative rehabilitation protocol was used.2 The protocol was identical to that used for patients who undergo a reconstruction using a standard technique. Patients were placed in a hinged knee brace postoperatively, and weight-bearing ambulation was allowed with the brace locked in extension. The brace was unlocked or removed to allow for range-of-motion exercises. Bracing was discontinued 6 weeks postoperatively for autografts and within 3 weeks for allografts. Bracing was used in autograft patients for 6 weeks to protect the extensor mechanism from injury. In general, bicycling was allowed at 2 weeks, use of stair climbing machines at 4 to 6 weeks, straight-ahead jogging at 12 to16 weeks, and gradual return to sport between 4 and 6 months postoperatively if rehabilitation criteria were achieved.

Physical Examination

Follow-up physical examinations were performed by a sports medicine fellow independent of the treating surgeon. Evaluation included supine range of motion with a goniometer, prone heel-height differences, thigh circumference measurements and evaluation of patellofemoral crepitation. Physical examination tests included Lachman, pivot shift, anterior and posterior drawer, and varus-valgus stability at 30° of flexion. Ligamentous laxity was graded as 1+ (0-5 mm), 2+ (6-10 mm), or 3+ (11-15 mm). Pivot shift testing was graded as 1+ (slip), 2+ (jump), or 3+ (transient lock) in the position of thigh abduction and external rotation, which maximizes the pivot shift phenomenon.[4]

Functional Examination

All patients underwent bilateral knee functional testing at follow-up examination by an experienced athletic trainer (J.B.). Functional tests recorded included timed single-leg 6-m hop, single-leg hop for distance, and vertical jump. Patients underwent three trials on each leg. The results were averaged, and a side-to-side comparison was performed and reported as a percentage difference.

Arthrometric Testing

All patients underwent arthrometric testing preoperatively and at final follow-up using the KT-1000 arthrometer (MedMetric, San Diego, Calif). Examinations were performed by an experienced athletic trainer (J.B.) using a standard technique.[3,7] Anterior manual maximum and manual maximum side-to-side differences were calculated. An arthrometric failure was defined as side-to-side difference >5 mm.

Knee Rating Scores

A detailed questionnaire was developed to calculate Lysholm, Tegner, and Noyes Cincinnati scores.[15,19,24] Questionnaires were completed by patients to eliminate interviewer bias.

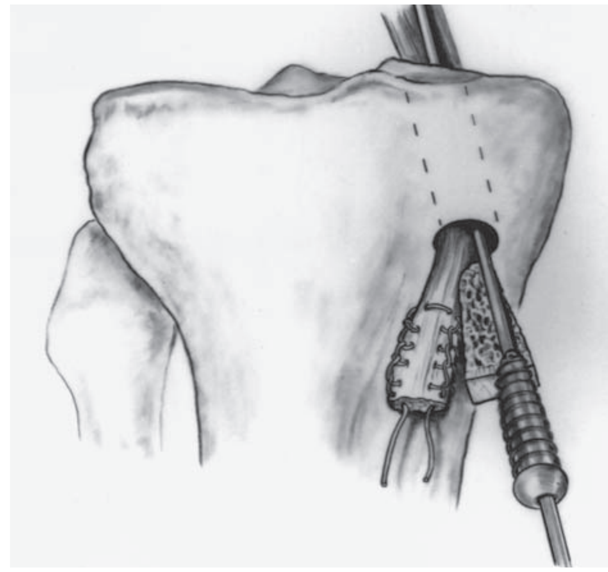


Figure 4. Diagram depicting the soft-tissue, free bone block, interference screw construct. The bone block is inserted into the tunnel flush with the tunnel edge prior to screw placement.

Subjective Assessment

Subjective patient satisfaction was evaluated using several methods. Patients were asked to respond with a simple "yes" or "no" regarding whether they would consider having the procedure on the opposite knee if faced with similar circumstances. They also were asked to categorize their satisfaction levels as "completely," "mostly," or "somewhat" satisfied, or "dissatisfied." Finally, a 10-cm visual analog scale was used to measure overall satisfaction and overall pain scores of the operative knee.

Data Analysis

Patient charts were reviewed independently of the surgeon by a sports medicine fellow or orthopedic resident. Preoperative, intraoperative, and postoperative data were obtained and entered into an IBM data acquisition computer system. Statistical analysis then was performed; the level of significance was set at $P<.05$.

RESULTS

Patient Population

Bone Block Group. This group included four men and five women. Average patient age was 31.7 (SD 12.8) years (range: 18-49 years). Seven right knees and two left knees underwent reconstruction. Average follow-up was 20 (SD 8.9) months (range: 13-40 months). Allografts were used in six patients, and autografts were used in three patients. Associated procedures performed at the time of ACL reconstruction included partial medial meniscectomy in one

TABLE 1

Comparison of Pre- and Postoperative Lachman and Pivot Shift Findings for Free Tibial Bone Block and 540° Graft Rotation Groups

	Bone Block Group (n=9)		540° Group (n=14)	
	Preoperative	**Postoperative**	**Preoperative**	**Postoperative**
Lachman				
0	0	5	0	11
1+	0	4	0	2
2+	7	0	10	1
3+	2	0	4	0
Pivot shift				
0	1	9	1	13
1+	3	0	2	1
2+	5	0	10	0
3+	0	0	1	0

patient, partial lateral meniscectomy in one patient, medial meniscal repair in two patients, and medial femoral condyle microfracture in one patient.

540° Group. This group included 2 men and 12 women. Average patient age was 28.6 (SD 14.1) years (range: 16-60 years). Seven right knees and seven left knees were reconstructed. Average follow-up was 34 (SD 11.3) months (range: 18-48 months). Allografts were used in 4 patients, and autograft were used in 10 patients. Associated procedures performed at the time of ACL reconstruction included partial medial meniscectomy in two patients, partial lateral meniscectomy in two patients, and lateral femoral condyle microfracture in one patient.

For this study, operative reports from 224 cases of primary ACL reconstructions were reviewed. The graft selection was patellar tendon autograft in 168 cases (75%) and allograft in 56 cases (25%). Overall, 28 cases of significant graft tunnel mismatch were identified for an incidence of 13%. Significance was defined as mismatch that was not correctable using simple femoral tunnel recession and that required either graft rotation of 540° or free bone block fixation. Eleven (39%) of these 28 cases were reconstructions using allografts. Thus, the incidence of significant graft tunnel mismatch was 20% for reconstructions using an allograft compared to 10% for reconstructions using an autograft. Six (55%) of the 11 free bone block reconstructions were allografts compared to 5 (30%) of 17 rotation reconsctructions.

The length of the ligamentous portion of the graft was noted in the operative reports of 26 patients. Overall, the average soft-tissue length of the graft was 50 mm. In patients who underwent bone block fixation, all 11 patients had documented graft lengths in the operative report; average graft length for this group was 52 mm (range: 48-63 mm). In patients who underwent 540° of graft rotation, 26 of 28 patients had a documented graft length; average graft length for this group was 48 mm (range: 43-58 mm).

Physical Examination

Table 1 summarizes preoperative and postoperative Lachman and pivot shift test findings.

Bone Block Group. Preoperatively, all patients had an

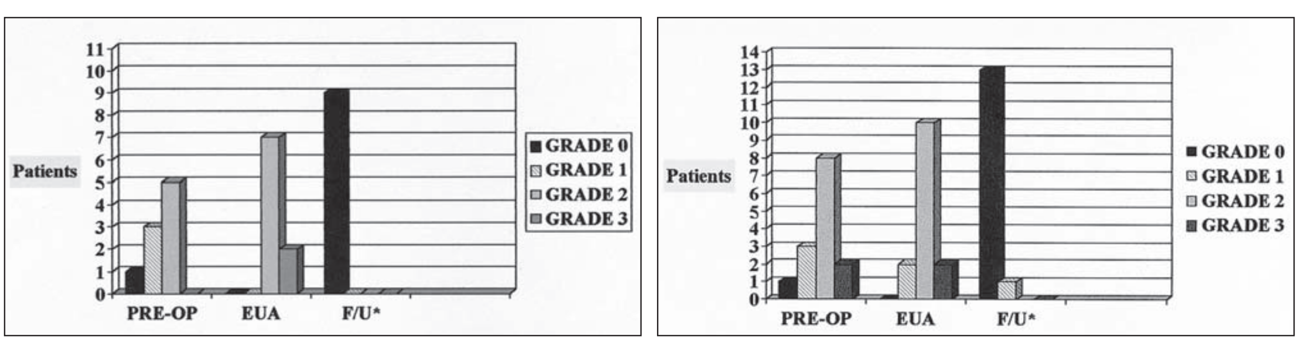


Figure 5. Graph depicting preoperative (PRE-OP), examination under anesthesia (EUA), and postoperative (F/U) pivot shift examination in the free bone block (A) and 540° graft rotation (B) groups. There was a statistically significant improvement at final follow-up in both groups.

TABLE 2

COMPARISON OF PRE- AND POSTOPERATIVE KT-1000 ARTHROMETER FINDINGS FOR FREE TIBIAL BONE BLOCK AND 540° GRAFT ROTATION GROUPS

	Bone Block Group (*n*=9)			540° Group (*n*=14)		
	Preoperative	Postoperative	*P* Value	Preoperative	Postoperative	*P* Value
Maximum manual translation (mm)						
Mean (SD)	14 (1.9)	6 (1.5)	.017	14 (1.6)	7 (2.2)	.012
Range	10-17	3-8		11-17	2-11	
Side-to-side difference (mm)						
Mean (SD)	6 (1.8)	-0.75 (2.1)	.007	7 (1.9)	0 (2.9)	.005
Range	2-8	-5 to 3		2-10	-5 to 8	

abnormal Lachman test and eight patients had an abnormal pivot shift test. All patients demonstrated a positive pivot shift when examined under anesthesia. No patient had significant varus or valgus laxity.

Postoperatively, five patients had a negative and four patients had a positive Lachman test. No patient had a positive pivot shift test (Figure 5A); postoperative improvement in pivot shift was statistically significant ($P=.024$). After reconstruction, average range of motion in the bone block group was from 3° (SD .5°) of hyperextension (range: 2°-3°) to 143° (SD 4.6°) of flexion (range: 137°-148°). Average prone heel-height difference was 0.3 cm (range: 0-2 cm).

540° Group. Preoperatively, all patients had an abnormal Lachman test and 13 patients had an abnormal pivot shift test. All patients demonstrated a positive pivot shift when examined under anesthesia. No patient had significant varus or valgus laxity.

Postoperatively, 11 patients had a negative and 3 patients had a positive Lachman test. Thirteen patients had a negative and 1 patient had a positive pivot shift (Figure 5B); postoperative improvement in pivot shift was statistically significant ($P=.023$). After reconstruction, average range of motion was from 3° (SD 1.0°) of hyperextension (range: 2°-5°) to 144° (SD 6.3°) of flexion (range: 132°-153°). Average prone heel-height difference was 0.1 cm (range: 0-1 cm).

Functional Examination

Bone Block Group. The mean deficit for the affected knee was 5% for the timed single-leg hop, 11% for the single-leg hop, and 13% for the vertical jump. All patients demonstrated <10% difference from the unaffected leg for the single-leg hop, 6 (66%) patients for the timed single-leg hop, and 6 (66%) patients for the vertical jump. No statistically significant differences were noted between the operative and nonoperative legs for any parameter.

540° Group. The mean deficit for the affected knee was 2% for the timed single-leg hop, 10% for the single-leg hop, and 5% for the vertical jump. Nine (70%) patients demonstrated <10% difference from the unaffected leg for the single-leg hop, 11 (85%) patients for the timed single-leg hop, and 10 (77%) patients for the vertical jump. No statistically significant differences were noted between the operative and nonoperative legs for any parameter.

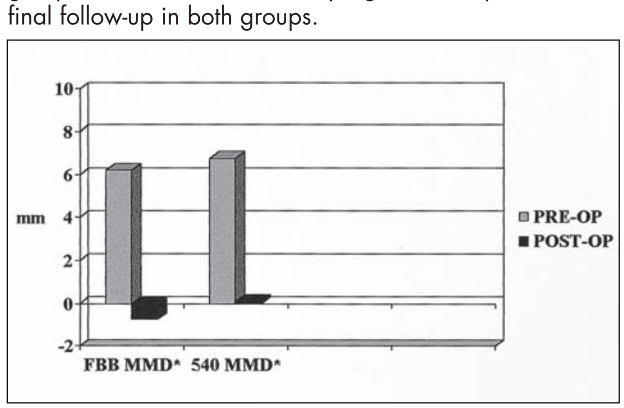
Arthrometric Evaluation

Table 2 summarizes mean preoperative and postoperative manual maximum translation and side-to-side differences for both groups.

Bone Block Group. Preoperatively, manual maximum testing revealed statistically significant differences between injured and uninjured knees ($P=.007$). Side-to-side differences were <3 mm in 1 (11%) patient and >5 mm in 8 (89%) patients.

Postoperatively, mean manual maximum translation in the affected knee was significantly reduced ($P=.017$) (Figure 6). Side-to-side differences also were significantly reduced ($P=.007$). Side-to-side differences were ≤3 mm in 8 (89%) patients and between 3 and 5 mm in 1

Figure 6. Graph depicting the preoperative and final follow-up arthrometric manual maximum side-to-side differences for the free bone block (FBB) and 540° graft rotation (540°) groups. There was a statistically significant improvement at final follow-up in both groups.



(11%) patient; no patient had a side-to-side difference >5 mm. No statistically significant difference was observed in mean manual maximum values between reconstructed and nonoperative knees (P=.343).

540° Group. Preoperatively, manual maximum testing revealed statistically significant differences between injured and uninjured knees (P=.002). Side-to-side differences were <3 mm in 1 (7%) patient, between 3 and 5 mm in 3 (21%) patients, and >5 mm in 10 (71%) patients.

Postoperatively, mean manual maximum translation was significantly reduced in the affected knee (P=.012.) (Figure 6). Side-to-side differences also were significantly reduced (P=.005). Side-to-side differences ≤3 mm in 10 (69%) patients, between 3 and 5 mm in 3 (23%) patients, and >5 mm in 1 (8%) patient. No statistically significant difference was observed in manual maximum values between reconstructed and nonoperative knees (P=.511).

Knee Rating Scores

Bone Block Group. Mean postoperative Lysholm score was 91 (range: 73-100). Using this scoring system, four patients were classified as excellent, three as good, and two as fair; no patient was classified as poor. Mean postoperative Tegner scale was 7.6 (range: 4-10). Mean postoperative Noyes sports activity scale was 83 (range: 55-100). Mean postoperative International Knee Documentation Committee (IKDC)-9 score was 89 (range: 74-100).

540° Group. Mean postoperative Lysholm score was 85 (range: 56-100). Using this scoring system, 4 patients were classified as excellent, 5 patients as good, 4 patients as fair, and 1 patient as poor. Mean postoperative Tegner scale was 7.8 (range: 5-9). Mean postoperative Noyes sports activity scale was 85 (range: 60-95). Mean postoperative IKDC-9 score was 83 (range: 63-97).

Subjective Results

Bone Block Group. All patients reported they were completely or mostly satisfied. All patients also reported that under similar circumstances, they would undergo the procedure again. Using a 10-cm visual analog scale, patients rated mean overall satisfaction with their knee as 8.6 (range: 6-10). Using a similar scale, patients rated their mean overall pain score with regard to the operative knee as 2 (range: 1-3).

540° Group. All patients reported they were completely or mostly satisfied. All patients also reported that under similar circumstances, they would undergo the procedure again. Using a 10-cm visual analog scale, patients rated mean overall satisfaction with their knee as 8 (range: 6-10). Using a similar scale, patients rated their mean overall pain score with regard to the operative knee as 0.67 (range: 0-1).

Complications

No patellar fractures, patellar tendon ruptures, neurovascular injuries, or thromboembolic complications occurred in either group. A total of three (13%) patients required reoperation. One bone block patient required reoperation for a partial medial meniscectomy following a failed meniscal repair. In the 540° group, one patient required arthroscopic irrigation and debridement for infection, which subsequently resolved with retention of the graft. A second patient in the 540° group required arthroscopic lysis of adhesions for postoperative stiffness.

DISCUSSION

Graft tunnel mismatch is a potential problem associated with endoscopic single-incision ACL reconstruction surgery with patellar tendon autograft or allograft.[21,22] Correct position of the bone tunnels is essential for achieving appropriate intra-articular graft length as well as preventing graft impingement, laxity, flexion contracture, and early failure.[9,10,17] Prevention of these problems is enhanced with accurate intra-articular measurement techniques as well as a thorough knowledge of ACL anatomy.[10,17] Yet, despite the best technique, problems with tunnel placement and graft tunnel mismatch may still occur.

A tibial tunnel that is too short results in the bone block extending from the tunnel, preventing interference screw fixation. A tunnel that is too long makes distal fixation and femoral tunnel placement difficult. Studies have demonstrated the rate of graft tunnel mismatch to be as high as 26%.[21,22] At the authors' institution, the "N+10" rule is used to determine tunnel length. This is an adaptation of the method initially described by Miller and Hinkin.[16] In using this adaptation, the angle for the tibial bone tunnel guide is determined by measuring the tendinous portion of the graft and adding 10; for example, a 45-mm tendon would have the tibial tunnel drilled at a 55° angle. As the angle of the tibial tunnel is increased, the length of the tunnel also increases. However, it should be noted angles >60° are not used as this may result in a graft that is vertically oriented. In their original article, Miller and Hinkin stated the N+7 rule reduced the frequency of graft tunnel mismatch to 1%, but the present study as well as others have reported this rate to be much higher.[21,22]

In this study, operative reports from 224 ACL reconstructions were reviewed. Overall, 28 cases of significant graft tunnel mismatch were identified. This corresponds to an incidence of 13%, which is consistent with previous reports.[16,21,22] The incidence of significant graft tunnel mismatch when using an allograft for reconstruction was much higher at 20%. In the free bone block group, 6 (55%) of 11 reconstructions were allografts compared to

5 (30%) of 17 reconstructions in the 540° of graft rotation group technique. These data would seem to indicate graft tunnel mismatch is more common and often of greater magnitude with allograft reconstructions. This difference may be related to differences in the size of the patient versus the size of the donor. Although requests can be made for allograft size based on patient height, factors such as errors in measurement on the part of the bone bank and limited availability of grafts can lead to a significant difference in the size of the graft versus the size of the patient and an increased potential for graft tunnel mismatch.

Previous reports also have reported the incidence of graft tunnel mismatch to be increased when the tendinous length of the graft is >50 mm.[21] In this study, the average tendinous graft length was 48 mm. However, when the groups were analyzed independently, the average tendinous length was 52 mm for the bone block group compared to 48 mm for the 540° group; this difference was statistically significant. Thus, in severe cases of graft tunnel mismatch requiring a free bone block technique for tibial fixation, the average graft length was >50 mm.

When graft tunnel mismatch occurs, multiple methods of addressing the problem have been proposed. Black et al[6] demonstrated the length required for adequate interference screw fixation in a porcine hindquarter model could be decreased to 12.5 mm with no significant difference in torque, divergence, stiffness, displacement, or load to failure. Taylor et al[23] reported no difference in postoperative KT-1000 arthrometry results in a group of 100 patients managed with femoral plug recession at 1-year follow-up. However, potential disadvantages to this technique include the potential for graft laceration by the interference screw and a potential alteration in the femoral isometric point of the graft. Barber[5] reported a technique of flipping one bone plug 180° over its ligamentous insertion, thus shortening the intra-articular length. This technique demonstrated 86% good and excellent results and 92% arthrometric stability at last follow-up in 50 patients. Fowler and DiStefano[11] described another technique that used an autograft cancellous core of bone placed in the tibial tunnel followed by interference screw fixation.

A final option for addressing graft tunnel mismatch is to convert to a two-incision technique. This technique involves using an accessory lateral incision for placement of the femoral tunnel. The advantages of this technique are it eliminates the complications associated with the endoscopic femoral tunnel placement such as posterior wall blow-out as well as problems with graft tunnel mismatch. The disadvantage of this technique is the necessity for a second incision and the associated dissection to retract the vastus lateralis. However, multiple studies have demonstrated equivalent results between an endoscopic and two-incision technique.[13,14,20]

At the authors' institution, two different methods of dealing with graft tunnel mismatch are used. The first involves graft rotation in which the graft is externally rotated 180° prior to tibial fixation with an interference screw. This allows for the tibial screw to be placed against the cortical surface of the tibial plug, anterior to the graft. The benefits of this technique are three-fold. First, with the screw anterior to the tibial bone block, the graft is pushed to a more posterior anatomic position. Second, with the screw on the cortical side, cancellous-to-cancellous bone healing is obtained, which has been shown to be stronger than cortical-to-cancellous bone fixation. Finally, if the screw is inserted beyond the tendo-osseous transition, graft laceration does not occur if the screw is anterior to the graft, whereas if placed posteriorly, the tip of the screw could abrade or penetrate the graft. In cases in which graft tunnel mismatch exists, an additional 360° of external rotation is added, for a total rotation of 540°. This added rotation serves to shorten the graft. Rotation of the graft combined with recession of the bone block in the femoral tunnel, shortening of the tibial bone block, or both can rectify most cases of graft tunnel mismatch up to 10 to 12 mm. In cases in which larger degrees of mismatch occur, a free bone block technique is used. The use of one of these two techniques can address all cases of graft tunnel mismatch.

Both methods of fixation have been studied in the laboratory to evaluate their initial failure characteristics. Verma et al[25] evaluated the ultimate failure strength of porcine bone-patellar tendon-bone grafts with various degrees of rotation and found no significant difference in initial failure strength in grafts rotated 0°, 90°, 180°* and 540°. They also determined grafts rotated 540° were shortened an average of 5.4 mm. However, a statistically significant increase in strain was noted in grafts rotated 540°. It was hypothesized this could potentially result in increased knee laxity in knees reconstructed with rotated grafts.

More recently, a study was conducted to determine the effect of graft rotation on anteroposterior (AP) knee laxity and graft force.[12] Thirteen fresh-frozen human knee specimens received bone-patellar tendon-bone allografts. The effects of 90° and 180° of internal and external rotation on AP graft laxity and graft force then were measured. The authors determined rotation of the graft after pretensioning resulted in a decrease in AP laxity with the knee flexed 30° for grafts externally rotated 90° and an even further decrease in AP laxity in grafts externally rotated 180°. There was no difference in AP laxity for grafts rotated and then pretensioned. It also was determined graft force increased 24 N for grafts externally rotated 180°. The authors hypothesized increasing graft rotation beyond 180° to correct for graft tunnel mismatch would result in undo tension on the graft and potentially compromise clinical outcome.

Similarly, initial graft fixation strength was studied by Novak et al[18] in a screw-and-post model verses free bone block interference screw fixation. Using a bovine knee model, 28 knees randomly divided into two groups were tested using an Instron material testing machine. They found the maximum load to failure of the screw-and-post model to be 374 N versus 669 N in the free bone block interference screw group.

Reports of clinical studies on rotated grafts or grafts fixed with a free bone block technique have been limited. In 1999, Auge and Yifan[1] reported up to 25% shortening of the collagenous portion of the graft could be achieved with 630° of graft external rotation. They also reported on three patients who underwent this technique during ACL reconstruction to eliminate graft tunnel mismatch. At 1-year follow-up, all patients were stable with KT-1000 manual maximum differences <3 mm, and there was no difference in clinical outcome from anecdotal controls. Diduch et al[8] found no difference in KT-1000 side-to-side measurements in 60 patients with grafts rotated 90° versus 60 patients with no graft rotation at short-term follow-up. No reports of clinical follow-up of grafts fixed with a free bone block technique have been published.

In this study, the results obtained with rotated grafts and those fixed with a free bone block technique compare favorably to previously reported results of grafts fixed using a standard interference screw technique. A previously published report on 2-year follow-up results for ACL reconstruction using a standard endoscopic single incision technique demonstrated an incidence of positive postoperative pivot shift phenomenon of 9%.[2] Furthermore, 83% of patients had side-to-side arthrometric differences ≤3mm. Only 4 of 103 patients met the criteria for failure of arthrometric side-to-side difference >5mm or a positive pivot shift examination. Using the same criteria in this study, only 1 of 23 patients would be considered a failure.

There are some limitations to this study. First, this study was conducted in a retrospective manner and is subject to the errors inherently introduced by this scientific method. Second, the sample size for both patient study groups is small. Although the data were collected from 3 years of operative cases with more than 240 reconstructions performed, only 28 cases of graft tunnel mismatch were identified. Even at an institution where a large number of ACL reconstructions are performed annually, the incidence of patients with clinically significant graft tunnel mismatch requiring one of these two techniques is small, making larger sample sizes difficult to obtain. Furthermore, it would not be possible to randomize patients to different technique groups as the technique that is selected is dependent on the degree of mismatch.

CONCLUSION

Graft tunnel mismatch is a problem encountered with single-incision endoscopic technique using bone-patellar tendon-bone autograft or allograft for ACL reconstruction. Various techniques mostly using alternative methods of fixation have been used to deal with this problem. This study demonstrated an incidence of clinically significant graft-tunnel mismatch of 13%. Clinically significant mismatch was more common and of higher magnitude in allograft reconstruction. Results indicate graft rotation is an effective way of addressing smaller degrees of mismatch up to 12 mm, while a free bone block fixation technique is an effective way of addressing larger mismatches. Both methods yielded clinical and functional outcomes comparable to conventional endoscopic reconstruction at short-term follow-up.

This subgroup of ACL reconstruction patients will be monitored carefully, with particular interest given to the 540° rotation subgroup, which had a 23% incidence of KT-1000 translations between 3 and 5 mm. At this preliminary evaluation, there may be cause for concern as the percentage of patients within this range merits careful observation. Finally, cyclic loading bovine model has been initiated to study the biomechanical effects of hyperrotation.

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