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The Influence of Reverse-Thread Screw Femoral Fixation on Laxity Measurements After Anterior Cruciate Ligament Reconstruction With Hamstring Tendon*

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ABSTRACT

In arthroscopically assisted anterior cruciate ligament reconstruction using hamstring tendon graft, the graft rotates slightly as the femoral screw is inserted. Its final position tends to be in the anterior half of the tunnel in right knees, resulting in clinical laxity. To perform identical procedures on left and right knees, a reverse-thread screw was designed for femoral fixation in right knees. We prospectively studied 80 patients undergoing right-knee anterior cruciate ligament reconstruction with hamstring tendon autograft. Thirty-six patients underwent reconstruction with a standard screw and 44 underwent reconstruction with a reverse-thread screw. The same technique, performed by the same surgeon, was used on all patients. At 12 months' follow-up, the average side-to-side differences on arthrometry testing were 2.00 mm for the standard screw group and 0.95 mm for the reverse-thread screw group using a manual maximum test, and 1.66 mm and 1.00 mm, respectively, using the 20-pound test. Both differences were statistically significant. Of the standard group, 23% had a manual maximum difference of 3 mm or more, compared with 8% of the reverse-thread group. A significant difference was found between these two groups for Lachman test (77% with grade 0 for the standard group compared with 92% for the reverse group) but pivot shift and Lysholm knee score were not significantly different. The use of a reverse-thread screw for femoral fixation in right-knee anterior cruciate ligament reconstructions in men significantly decreased laxity at 12 months after surgery compared with standard screw fixation.

Successful arthroscopically assisted ACL reconstruction relies on exacting anatomic placement of the graft.[6,9,13,14] Considerable research has been performed emphasizing the importance of isometric points of attachment and the concept of isometry,[8] but attention has also focused on anatomic points of attachment and theoretic anatomic graft placement.[7,14]

Correct anatomic positioning of the femoral attachment is considered more important than that of the tibial attachment.[1,3,7,9] Studies have shown that altering the femoral graft attachment has a much larger effect than altering the tibial attachment.[10,12] The effective positioning of the femoral graft attachment has a great influence on laxity after ACL reconstruction.[2,4]

While the absolute position of the femoral tunnel has been defined anatomically,[7] the ultimate graft position within the tunnel after fixation has not been well addressed in the literature.[16] In ACL reconstruction using hamstring tendons and interference screws, graft rotation can occur around the screw during femoral insertion. This rotation affects the final graft position within the bone tunnel.[15] Routinely, the graft rotates within the tunnel 30° to 90° as the screw is initially gaining purchase in the bone. Graft rotation is dictated by the number of turns before the screw "bites" and captures the graft against the wall of the femoral tunnel. The screw is placed eccentrically and the strands are incorporated as one tendon mass with a baseball whipstitch; thus, all four strands rotate as a single unit. It is the screw thread orientation (and thus the direction of rotation of the screw during insertion) that

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The related institution has a commercial interest in products named in this study.

determines the rotation of the graft. Graft rotation may be minimized by tensioning the graft during screw insertion.

Conventional thought dictates that performing a technically identical operation on opposite limbs should yield similar results. Yet, a previous study performed at our institution revealed a trend toward increased laxity on instrumented testing in right limbs that had undergone ACL reconstructions using hamstring tendon graft and interference screw fixation compared with left limbs undergoing the same procedure (L. A. Pinczewski et al., unpublished data, 1999). This observed difference may be related to a different final femoral graft position within the tunnel when using a standard-thread screw on left and right limbs.

To reproduce a mirror-image operation on right and left limbs, the final femoral graft position within the tunnel must be the same. Standard (clockwise) screw thread orientation produces clockwise rotation of the graft in left knees, resulting in a posterior final graft position. However, standard (clockwise) screw thread orientation results in an anterior final femoral graft position within the femoral tunnel in right knees. Therefore, to achieve a posterior final graft position in a right knee, to mirror the rotation of the left knee, a reverse-threaded screw (counterclockwise) was devised.

The purpose of this study was to determine whether use of a reverse-threaded interference screw in hamstring tendon ACL reconstruction would decrease instrumented anterior tibial translation when compared with a standard-threaded screw. Previous studies suggest that women may have increased laxity measurements with hamstring tendon grafts over their male counterparts (L. A. Pinczewski et al., unpublished data, 1999). Accordingly, to avoid this variable, the study was performed in male knees only.

MATERIALS AND METHODS

Ninety-five consecutive male patients underwent a right-knee ACL reconstruction with interference screw fixation of a hamstring tendon autograft between January 30 and October 1, 1997. Fourteen patients were excluded from the study group because they had a contralateral ACL injury; 13 patients had suffered the injury before the surgery described here and 1 patient had suffered a contralateral ACL injury 11 months after surgery. One further patient was excluded because he received only a two-strand hamstring tendon graft. The study group thus consisted of 80 patients.

All surgeries were performed by the senior author (LAP). A 7 × 25 mm interference screw with an 8-mm round head cannulated inside out (RCI; Smith and Nephew Acufex, Mansfield, Massachusetts) was used for femoral fixation in the first 36 patients (standard screw group) and a reverse-thread RCI screw (Smith and Nephew Acufex) was used in the next 44 patients (reverse screw group). A standard RCI screw was used for tibial fixation in all subjects.

Operative Technique

The minimally invasive arthroscopically assisted ACL reconstruction using a hamstring tendon autograft (gracilis and semitendinosus tendons) with interference screw fixation was performed in all patients. This technique has been previously described.[11] Femoral tunnel location is referenced from the posterior cortex by the use of a right-angled probe through the anteromedial portal at a position of 11 o'clock for the right knee and 1 o'clock for the left knee. A spot 5 mm anterior to the posterior intercondylar cortex is marked with a 45° bone awl, allowing seating of a 4.5-mm drill as the knee is brought to full flexion before drilling through both femoral cortices. The posterior position of the 4.5-mm drill tunnel is then checked before graft harvest. In the event a more posterior position is achieved, removal of the wall of the femoral tunnel occurs only at the internal aperture and proceeds 30° anteriorly into solid femoral bone. Hamstring tendon graft harvest, preparations, and sizing are then performed. Tibial tunnel location, drilling, guide pin insertion, and over-reaming are performed with the tunnel in the posterior footprint of the ACL tibial insertion.

The hamstring tendon graft is then delivered through the tibial and femoral tunnels within a lead suture in a retrograde direction. Once the graft is seated, the knee is fully flexed before femoral screw insertion via the anteromedial portal. The graft is tensioned by proximal lead suture and distal suture attachment to the graft, minimizing the tendency of the graft to rotate.

The femoral screw is inserted over a blunt pin that is placed through the anteromedial portal into the femoral tunnel anterior to the graft. The screw is engaged until purchase is firm and the head is countersunk 5 mm below the tunnel entrance. Once the screw is inserted, the fixation is checked by manual graft tension.

Tibial fixation is performed with the standard RCI screw over a blunt guide pin inserted inferiorly in the tibial tunnel. The graft is tensioned manually and the screw is initially engaged with the knee in flexion with final seating of the screw in extension.

Postoperative Rehabilitation

Patients were managed immediately postoperatively with the commencement of an accelerated rehabilitation program. No brace was required and patients discarded crutches as soon as possible after surgery, usually after 3 to 4 days, with full weightbearing encouraged. Standard clinical review was at 2 weeks, 6 weeks, 6 months, and 12 months. Patients attended daily physical therapy sessions for the first week, focusing on achieving full extension and quadriceps muscle strengthening. Running was permitted at 6 weeks, but return to competitive sport was restricted until 6 months and only after full review by the surgeon.

Assessment

In the current study, patients were assessed at 6 and 12 months after surgery by a single examiner who was not involved in the care of the patients. Assessment included the Lysholm knee score and the International Knee Documentation Committee (IKDC) standard evaluation. Instrumented testing was performed using the KT-1000 arthrometer (MEDmetric Corporation, San Diego, California). Thigh atrophy was determined from the side-to-side difference on thigh circumference at a point 10 cm above the superior pole of the patella. Patients were also questioned regarding the intensity and location of pain during kneeling and in the hamstring muscle.

Statistical Analysis

All data were analyzed using SPSS (SPSS, Inc., Chicago Illinois) version 7.5 for Windows software. For comparisons between the two groups Mann-Whitney tests were used for all ordinal and interval data and chi-square tests were used for nominal data. The level of statistical significance was set at $P \leq 0.05$.

RESULTS

The mean age of the patients in this study was 27 years (range, 14 to 51). The ACL was reconstructed in the subacute phase (3 to 12 weeks from injury) in 43 patients (54%) and in the chronic phase (>12 weeks from injury) in 37 patients (46%). At arthroscopy, a midsubstance rupture of the ACL was found in 69 knees (86%), a proximal rupture was noted in 6 (8%), and the location of rupture was unknown in 5 (6%). The median femoral graft size was 7.5 mm (range, 6.5 to 8.5). Seventy-seven patients underwent reconstruction using their ipsilateral hamstring tendons and three patients underwent reconstruction with their contralateral hamstring tendons. The hamstring tendon graft was 4 strands in 74 patients and 3 strands in 6 patients. There was no significant difference between the three- and four-strand grafts in terms of mean or median graft diameter.

A meniscectomy was performed in 33 patients (41%) at the time of ACL reconstruction. Seven patients (9%) had undergone meniscectomy before the ACL reconstruction.

At 12 months after surgery, three patients had ruptured their grafts: two patients from the standard screw group suffered graft rupture at 5 and 8 months, respectively, and one patient from the reverse screw group suffered a graft rupture at 3 months after surgery. The results of these three patients were excluded from further analysis. Of the remaining 77 patients, 68 (88%) were assessed at 12 months. Nine patients were lost to follow-up: four were overseas, two could not be located, and three were unable or unwilling to attend. The results of the remaining 68 patients, 30 from the standard screw group and 38 from the reverse screw group, are reported.

There was no statistically significant difference between the two groups in any of the following variables:

- Time between injury and surgery
- Articular surface damage
- Incidence of previous meniscectomy (4 patients [13%] in the standard screw group versus 3 patients [8%] in the reverse screw group)
- Meniscectomy at the time of ACL reconstruction (15 of 30 [50%] in the standard screw group and 18 of 38 [47%] in the reverse screw group)
- Femoral or tibial graft size (median femoral diameter 7.5 mm and median tibial diameter 7.5 mm for both groups)

A concurrent medial ligament injury was present in four patients from each group. These injuries were treated nonoperatively with a hinged brace applied in six patients, and two patients from the standard screw group underwent a repair at the time of ACL reconstruction.

TABLE 1
Lysholm Knee Scores in Patients with Standard Screw Fixation and Those with Reverse-Thread Screw Fixation[a]

Score	Standard (N = 30) N (%)	Reverse thread (N = 38) N (%)
Excellent (95–100)	18 (60)	18 (47)
Good (84–94)	10 (33)	13 (34)
Fair (65–83)	2 (7)	6 (16)
Poor (<64)	0	1 (3)
Median score	97	94
Range	75–100	64–100

[a] No significant difference between groups.

Lysholm Knee Score

Subjective assessment was performed using the Lysholm knee score (Table 1). The median Lysholm knee score was 97 for the standard screw group and 94 for the reverse screw group (no statistically significant difference). Ninety-three percent of the standard screw group and 82% of the reverse screw group reported good or excellent results (no statistically significant difference).

There was one patient in the reverse screw group who reported poor results. He reported occasional instability in daily activities and pain and swelling on heavy exertion. This patient had a grade 0 Lachman test and a negative pivot shift test, but he did have 2.5 cm of quadriceps muscle wasting in the operated limb.

IKDC Assessment

Overall IKDC assessment revealed 25 patients (83%) in the standard screw group and 27 patients (71%) in the reverse screw group were assessed as normal (A) or nearly normal (B). This was not determined to be a statistically significant difference (Mann-Whitney test, $P = 0.24$). If the patients who experienced a graft rupture are assumed to have an overall score of D, then in the standard screw group 78% (25 of 32) had normal or nearly normal ratings and in the reverse screw group 69% (27 of 39) had normal or nearly normal ratings.

On subjective functional assessment, all patients in both groups reported their result as normal (A) or nearly normal (B). With regard to symptoms, there was no statistically significant difference found between the two groups for pain, swelling, partial giving way, or full giving way with moderate to strenuous activities (Table 2).

TABLE 2
Number of Patients with No Symptoms with Moderate to Strenuous Activity in the Standard Screw Fixation and Reverse-Thread Screw Fixation Groups[a]

Symptoms	Standard (N = 30) N (%)	Reverse thread (N = 38) N (%)
No pain	26 (87)	31 (82)
No swelling	27 (90)	34 (89)
No partial giving way	30 (100)	36 (95)
No full giving way	30 (100)	37 (97)

[a] No significant difference between the groups.

TABLE 3
Ligament Evaluation Findings in Patients with Standard Screw Fixation and Those with Reverse-Thread Screw Fixation

Test	Standard (N = 30) N (%)	Reverse thread (N = 38) N (%)
Lachman[a]		
Grade 0	23 (77)	35 (92)
Grade 1	7 (23)	3 (8)
Pivot shift		
Grade 0	29 (97)	36 (95)
Grade 1	1 (3)	2 (5)

[a] A significant difference was found between the groups on Lachman testing (Mann-Whitney, P = 0.04).

Range of motion analysis revealed the side-to-side difference in extension was 3° or less (A) in 90% of the standard screw group (27 of 30) and in 89% of the reverse screw group (34 of 38). The side-to-side difference in flexion was 5° or less (A) in 93% of the standard screw group (28 of 30) and 97% of the reverse screw group (37 of 38).

A grade 0 Lachman test (A) was demonstrated in 77% of the standard screw group (23 of 30) and 92% of the reverse screw group (35 of 38). This was shown to be a statistically significant difference (Mann-Whitney test, P = 0.04). There was no significant difference between the groups on pivot shift testing. All patients in both groups were graded as normal (grade 0) or nearly normal (grade 1) on all ligament tests (Table 3).

Further information from the assessment with regard to joint crepitus, harvest site tenderness, single-legged hop test, current activity level, thigh atrophy, kneeling pain, and hamstring muscle pain revealed no significant difference between the groups.

Instrumented Testing

The results of instrumented testing are shown in Table 4. A significant difference was demonstrated between the mean anterior displacement of the two groups on testing at 20 pounds and at manual maximum testing. On 20-pound testing, 77% of the standard screw group (23 of 30) and 92% of the reverse screw group (35 of 38) scored 3 mm or less difference. On manual maximum testing, 67% of the standard screw group (20 of 30) and 89% of the reverse screw group (34 of 38) scored 3 mm or less difference.

TABLE 4
Results of Instrumented Testing Using KT-1000 Arthrometer in Patients with Standard Screw Fixation and Those with Reverse-Thread Screw Fixation

Arthrometry test	Standard RCI screw	Reverse-thread RCI screw
20 pound[a]		
Mean ± SD (mm)	1.7 ± 1.1	1.0 ± 1.1
Percentage <3 mm	77	92
Manual maximum[b]		
Mean ± SD (mm)	2.0 ± 1.4	1.0 ± 1.4
Percentage <3 mm	67	89

[a] Significant difference between the two groups (P = 0.008).
[b] Significant difference between the two groups (P = 0.002).

DISCUSSION

The aim of ACL reconstruction is to place and secure a graft in an anatomic position and to approximate as closely as possible normal knee kinematics. The principles of anatomic graft positioning and anatomic graft fixation are important in minimizing graft elongation with postoperative rehabilitation, leading to a more stable long-term result.[1,6,8–10,12,14]

When considering reconstructive surgery on opposite limbs using a hamstring tendon graft, attention must be given to the effect of screw thread-induced graft rotation to ensure that graft fixation is replicated in the right and left limbs. The senior author (LAP) recently completed a follow-up study on 215 patients who had undergone arthroscopically assisted isolated ACL reconstruction with hamstring tendon autograft (L. A. Pinczewski et al., unpublished data, 1999). The findings of that study revealed that there was a significant difference between the left and right knees on instrumented testing with a KT-1000 arthrometer at 20 pounds (mean of left knees, 0.9 mm, versus mean of right knees, 1.9 mm, P = 0.001). On manual maximum testing the mean displacement was 1.6 mm for the left knees and 2.1 mm for the right knees; however, this was not found to be a statistically significant difference (P = 0.06). There was also no significant difference between the left and right knees on pivot shift and Lachman testing. On the basis of this *trend* toward increased laxity in right knees, the authors hypothesized that the difference between opposite limbs could be a result of the final graft position within the femoral tunnel.

Hamstring tendon graft rotation during femoral screw insertion is observed intraoperatively to be dictated by screw-thread orientation. With a standard screw, clockwise graft rotation occurs, resulting in a posterior final graft position in left knees but a relatively anterior final graft position in right knees. The more anterior position observed in right knees may contribute to the increased laxity. The reverse-thread screw produces counterclockwise graft rotation in right knees, resulting in a posterior final graft position that mirrors the effect of a standard screw in left knees.

The results of the current study support the hypothesis that postoperative anterior laxity of ACL-reconstructed right knees is affected by the thread direction of the femoral screw, despite our best attempts to prevent this. Subjective assessments such as the Lysholm knee score and subjective IKDC assessment categories were unaffected by the use of the reverse-thread screw. There was, however, a significant difference between the two groups on Lachman testing and instrumented testing with the KT-1000 arthrometer. Lachman testing demonstrated grade 0 in 23 patients (77%) in the standard screw group and in 35 patients (92%) in the reverse screw group ($P = 0.04$). Instrumented testing with the KT-1000 arthrometer revealed a decrease in side-to-side difference in anterior laxity from 1.7 mm in the standard screw group to 1.0 mm in the reverse screw group ($P = 0.008$) with 20-pound testing. This was also supported by the decrease in mean side-to-side difference on manual maximum testing from 2.0 mm in the standard screw group to 1.0 mm in the reverse screw group ($P = 0.002$).

Although there was no significant difference observed between the groups on subjective assessment such as the Lysholm knee score, the aim of this study was to investigate a previously observed trend in increased laxity of right knees compared with left knees on KT-1000 arthrometer testing. Our aim was to examine whether the use of a reverse-thread screw would affect the objective trend previously observed. The desire to create an identical operation in the same-side limbs may be of future relevance with regard to the viscoelastic properties of the hamstring tendons in vivo over time. The difference in fixation may be reflected in subjective evaluations such as the Lysholm knee score at longer follow-up.

The interpretation that the final femoral graft position as dictated by screw-thread orientation is responsible for the observed difference in laxity requires consideration. Alterations in the femoral attachment of the graft in ACL reconstructions have been observed to have a larger effect on clinical laxity than altering the tibial attachment.[2,4,10] The focus in recent years within the literature has therefore been on proper positioning of the femoral tunnel in ACL reconstruction. Good clinical results have been found to correlate with a posterior femoral tunnel placement.[12] However, while the absolute femoral tunnel position is defined by anatomic reference points intraoperatively and on postoperative radiographs, final graft position within the tunnel is not well addressed in the literature.[4]

Optimal position of the interference screw with reference to the bone plug in patellar tendon ACL reconstruction has been studied extensively, and suggestions have been made with regard to orientation of the cortical or cancellous surface during screw insertion.[15] However, the results of patellar tendon ACL reconstruction cannot be extrapolated to the placement of hamstring tendon grafts.[4]

Eccentric versus central interference screw position in relation to the hamstring tendon graft within the femoral tunnel has recently been reported with regard to pull-out strength, with no significant difference observed.[16] However, no reference was made regarding the effects on clinical laxity.

In our experience an eccentric screw insertion position over a blunt guide pin is recommended. This sets the hamstring tendon graft in an initial posterior position within the femoral tunnel. The use of a reverse-thread screw in a right knee maintains this posterior position and reduces postoperative clinical laxity. Rotation of the graft itself during insertion, or "pretwisting" the graft, has been shown to have no significant effect on clinical knee laxity.[5] The position of the knee during graft fixation affects knee kinematics only in nonideally placed grafts.[6] The present study emphasizes the importance of graft rotation to a posterior position within the femoral tunnel as an important determinant of laxity, rather than the intrinsic graft rotation or fixation position of the knee.

In addition to the effect of the reverse-thread screw in right knees, posterior placement of the graft during insertion allows greater visualization, as the graft is not rotated to obscure the view. The use of a standard screw in a right knee rotates the graft into view, complicating visualization during insertion.

This study demonstrates that anterior laxity after ACL reconstruction using hamstring tendon is affected by graft position within the femoral tunnel as dictated by reverse- and standard-thread screws in right knees. We recommend that a reverse-thread screw be used for femoral fixation in right knees and a standard-thread screw be used in left knees to achieve a symmetric posterior anatomic graft position.

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