

Correlation of Interference Screw Insertion Torque With Depth of Placement in the Tibial Tunnel Using a Quadrupled Semitendinosus-Gracilis Graft in Anterior Cruciate Ligament Reconstruction

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Purpose: To evaluate the insertion torque of a soft-tissue interference screw in relation to depth of insertion into the tibial tunnel when used for fixation of a quadrupled semitendinosus-gracilis autograft in anterior cruciate ligament reconstruction. **Type of Study:** Biomechanical cadaver study. **Methods:** Ten quadrupled semitendinosus-gracilis grafts were harvested from fresh-frozen cadaver knees and fixed in donor proximal tibias using 10-mm bioabsorbable interference screws (Arthrex, Naples, FL). A cannulated torque screwdriver was used to measure screw insertion torque at 3 depths in the tibial tunnel: the outer cortex (distal third), the articular surface (proximal third), and between these 2 points (middle third). **Results:** The mean insertion torques for the distal third, middle third, and proximal third were 8.7, 4.7, and 4.3 in/lb, respectively. The insertion torque was significantly higher at the outer cortex (distal third) than the middle third and proximal third (joint line of the tibial tunnel) ($P < .05$). **Conclusions:** Our results indicate a correlation between insertion torque and depth of placement of bioabsorbable interference screws used for fixation of a semitendinosus-gracilis graft. Lower insertion torque at the articular surface, resulting in lower peak load or pullout strength, may outweigh the proposed benefits of joint-line fixation of a semitendinosus-gracilis graft used for anterior cruciate ligament reconstruction. **Clinical Relevance:** Studies have suggested that anatomic proximal fixation of ACL grafts in the tibial tunnel produces stability similar to intact knees. The results of our study indicate that lower insertion torque at the articular surface results in lower peak load and pullout strength of the graft, which may outweigh the proposed benefits of joint-line fixation. **Key Words:** ACL reconstruction—Semitendinosus-gracilis graft—Interference screw—Torque.

Hamstring tendon autografts have regained popularity as a choice for anterior cruciate ligament (ACL) reconstruction because of evidence showing less morbidity associated with their use compared with patellar tendon grafts. However, patellar tendon

autograft remains the most commonly used graft and is considered the gold standard with which other techniques are compared. Secure initial fixation of the graft is essential for successful early rehabilitation before graft incorporation. With hamstring tendon, graft slippage or pullout from the tibial tunnel has been reported as the major mode of initial fixation failure with cyclic loading.¹⁻⁵ Fixation near the proximal end of the tibial tunnel has been advocated to increase stability, minimize graft elongation and bone tunnel widening from graft-tunnel mismatch, and avoid the windshield-wiper effect.⁶⁻⁸ Several investigators have shown a correlation between insertion torque of the interference screw, specimen bone density, and peak load or pullout strength of the graft.⁸⁻¹²

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The purpose of this study was to evaluate the insertion torque of a soft-tissue interference screw in relation to depth of insertion into the tibial tunnel when used for fixation of a quadrupled semitendinosus-gracilis autograft in ACL reconstruction.

METHODS

Ten human cadaver knee specimens were obtained from the Medical Education Research Institute, Memphis, TN. Donors ranged in age from 29 to 47 years (average, 40.4 years). Specimens were thawed to room temperature no more than 24 hours before simulated ACL reconstruction was performed.

Surgical Technique

Procedures were performed in a simulated clinical setting with whole legs attached to the torso. Although an open technique was performed, endoscopic ACL reconstruction was simulated. Ipsilateral semitendinosus and gracilis (STG) tendons were harvested through an incision 2 cm distal and 3 cm medial to the tibial tuberosity using a commercially available tendon stripper (Arthrex, Naples, FL). Each tendon was doubled over a nonabsorbable No. 5 suture for traction, with the ends of the semitendinosus sutured to the looped end of the gracilis (a reversed gracilis loop opposite the semitendinosus loop to make the graft more uniform in size). Quadrupled grafts were created by suturing the 4 strands together, 3 cm at each terminal, with a No. 2 absorbable suture. Tunnels were reamed 2 mm smaller than the precisely measured tendon graft ends, then dilated in 0.5-mm increments to the graft end to be secured in that tunnel. Standard tibial and femoral tunnels were made using Arthrex ACL reconstruction instrumentation. A notch for screw insertion was made in the anterior portion of the femoral tunnel. The graft was inserted through the tibial tunnel into the femoral tunnel with a suture eye guide pin brought out through the anterolateral femoral cortex. With the knee in maximal flexion to allow screw insertion parallel to the femoral tunnel, the STG graft was secured with a 23-mm bioabsorbable interference screw equal to the tunnel diameter. The tibial screw was inserted with the knee in 30° of knee flexion after maintaining 10 lb of tension on the graft for 3 minutes using a tensiometer. A fully threaded 28-mm Arthrex tapered-tip bioabsorbable interference screw with a diameter 1 mm larger than the tunnel diameter was inserted into the tibial tunnel until the screw end was flush with the tibial cortex. An Arthrex

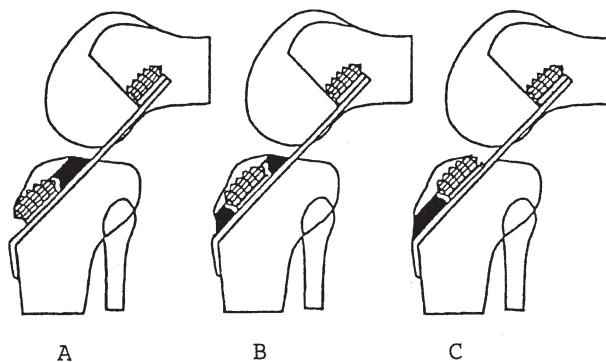


FIGURE 1. Tibial tunnel interference screw fixation points of the ACL graft. Insertion torque was recorded at the 3 sites commonly used and recommended for interference fixation: (A) distal third, (B) middle third, and (C) proximal third.

cannulated torque screwdriver was used to obtain screw insertion torque data at the tibial cortex. Insertion torque was measured as the screw was advanced to the middle third of the tibial tunnel and at the proximal third or tibial joint line. Screw depth was measured with a depth gauge and was visually confirmed. All torque tests were performed by the senior author. Torque measurements were recorded when the screw end was flush with the cortex, recessed 3 mm, and finally when the tip was flush with the joint line.

Data Analysis

Paired Student *t* tests were used to compare interference screw insertion torque at the distal third (outer cortex) of the tibial tunnel versus insertion torque at the proximal third (articular surface) and at the middle third of the tibial tunnel (Fig 1).

RESULTS

The mean insertion torque for the distal third (outer cortex), middle third, and proximal third (joint line) was 8.7, 4.7, and 4.3 in/lb, respectively. The insertion torque was significantly higher at the outer cortex (distal third) than at the middle third or proximal third (joint line) of the tibial tunnel ($P < .05$) (Table 1).

DISCUSSION

Recent studies suggest that proximal graft fixation in the tibial tunnel may be the best position for knee stability.¹³ Ishibashi et al.⁶ used a robotic testing system to assess the overall stability of porcine knees after ACL reconstruction with different sites of tibial

TABLE 1. Data Summary

Specimen ID	Age (yr)	Sex	Torque		
			Distal 1/3 (in/lb)	Middle 1/3 (in/lb)	Proximal 1/3 (in/lb)
05-06-40	35	F	12.6	4.4	5.0
05-06-40	35	F	12.0	5.2	4.2
04-28-35	47	F	4.0	2.6	2.6
04-28-35	47	F	4.6	2.4	2.4
01-06-01	46	M	5.2	2.8	2.8
01-06-01	46	M	7.0	5.2	2.2
01-02-01	45	M	2.4	2.0	2.0
01-02-01	45	M	8.8	2.4	2.4
07-07-62	29	M	17.6	10.0	9.6
07-07-62	29	M	12.8	10.0	9.4

graft fixation. Tibial graft site fixation had a significant effect on anterior displacement and internal rotation of the tibia as well as forces within the graft. Proximal fixation with an interference screw produced the most stable knees. Stability decreased with central tunnel interference screw fixation and became even less stable with more distal fixation, consisting of 2 staples just outside the tibial tunnel. The forces within the graft were closest to an intact ACL with proximal fixation, whereas more distal fixation resulted in significant reductions in graft forces. Ishibashi et al.⁶ attributed these findings to a reduction in overall graft stiffness with distal fixation, as well as size mismatch of a patellar tendon graft within the tibial tunnel. They believed that anatomic proximal fixation is best initially and provides stability similar to an intact knee.⁶ However, they did not evaluate insertion torque and graft pullout strength.

Morgan et al.⁷ evaluated ligament isometry in vivo during ACL reconstruction, varying the distal testing positions. Three points for distal fixation were tested, 1 proximally (anatomic) and 2 distally. They found that the distal (nonanatomic) positions produced more excursion of the graft than the proximal (anatomic) position. They concluded that distal fixation for an ACL graft may have a similar effect on elongation forces on the graft and potentially result in a wind-shield-wiper effect.⁷

The relationship between insertion torque, bone density, and pullout strength have been studied.^{9,10} C. H. Brown et al.⁹ compared fixation strengths of several methods of femoral fixation of patellar tendon bone blocks in elderly human cadavers with low bone density (0.23 to 0.34 g/cm³). They found a weak positive correlation ($R^2 = 0.45$, $P < .05$) between screw insertion torque and pullout force.⁹ G. A.

Brown et al.¹⁰ studied the correlation of insertion torque of interference screws to failure load of patellar tendon bone blocks in bovine, young human, and elderly human cadavers. Their results showed a significant correlation between insertion torque and failure load ($R^2 = 0.44$, $P < .0001$), as well as interference and insertion torque ($R^2 = 0.18$, $P < .003$) when all data were combined.¹⁰ Insertion torque and load at failure were less in the elderly cadavers than in the young cadavers, consistent with poorer bone quality and decreased bone density in the elderly group. They concluded that insertion torque is an independent predictor of failure load.¹⁰

McKeon et al.¹¹ evaluated the correlation of insertion torque of a soft-tissue bioabsorbable interference screw to the peak load at failure of a free central quadriceps tendon graft and specimen bone density. They found a high correlation between insertion torque and both peak load at failure ($R^2 = 0.86$) and mean bone density ($R^2 = 0.88$).

Caborn et al.¹⁴ compared femoral fixation of quadrupled semitendinosus-gracilis autografts using metal and bioabsorbable interference screws after bone mineral density assessment in cadaver specimens. In contrast to the study by McKeon et al., they concluded that insertional torque did not correlate ($P > .05$) to bone mineral density or maximum load at pullout. The average age of the cadavers in their study was 69.4 years.

Pena et al.¹⁵ compared failure strength of metal and bioabsorbable interference screws in patellar tendon bone blocks and the influence of insertion torque and bone mineral density in cadaver knees. The study used first- and second-generation bioabsorbable screws. They found higher insertion torques as well as higher load at failure with the use of metal screws. The first-generation bioabsorbable screws had higher insertion torques than the second-generation screws. They attributed the lower insertion torque of the second-generation screws to the use of notching instruments to prevent screw breakage during insertion. However, bone mineral density of the metal and first-generation bioabsorbable screw specimens was statistically higher than the bone mineral density of the second generation bioabsorbable screw specimens.¹⁵ This finding supports the correlation of insertion torque and bone mineral density.

Kohn and Rose¹⁶ compared the effectiveness of fixation of patellar tendon bone blocks with 9- and 7-mm interference screws in cadaver knees and the significance of torque during screw insertion. They plotted the maximum torque at insertion against the maximum tensile force at failure and concluded that

torque can be used as a predictor of pullout strength of bone block fixation.

We found a statistically significant higher insertion torque (mean 8.7 in/lb, $P < .05$) of interference screws that were placed at the distal third of the tibial tunnel (flush with outer cortex) in quadrupled semitendinosus-gracilis autografts. Interference screws placed at the distal third of the tibial tunnel had a 2-fold higher mean insertion torque (8.7 in/lb) than those placed in the middle third (4.7 in/lb) and proximal third (4.3 in/lb) of the tibial tunnel. The correlation between interference screw insertion torque and pullout strength of ACL autografts (bone block and soft tissue) is well supported in the literature.^{8-11,16} Secure initial graft fixation reduces the incidence of pullout failure and facilitates early rehabilitation and successful outcome after ACL reconstruction. Pullout strengths were not tested on the 3 screw positions. To perform a test at 1 position would disrupt the integrity of the graft and tunnel, invalidating further testing at the other screw positions.

Recent studies provide evidence that anatomic proximal fixation of ACL grafts in the tibial tunnel produces stability similar to intact knees.^{6,13,17} We have routinely secured grafts at the anatomic proximal position of the tibial tunnel during ACL reconstruction. The results of our study have shown the benefit of interference screw fixation at the distal third (outer cortex) of the tibial tunnel. We are now incorporating both concepts during ACL reconstruction procedures.

A shorter tibial tunnel is produced by setting the referencing guide angle at 45°, thus producing a tunnel approximately 35 mm in length. In this manner, interference screw fixation of the graft is achieved both proximally and at the outer cortex. If the interference screw is significantly shorter than the tunnel, then 2 screws can be used. Longer tapered Bioscrews (Arthrex) recently have been released that may also be used in this circumstance.

Our results indicate a correlation between insertion torque and depth of placement of bioabsorbable interference screws used for fixation of semitendinosus-gracilis autografts during ACL reconstruction. Lower insertion torque at the articular surface, resulting in lower peak load and pullout strength, may outweigh the proposed benefits of joint-line fixation of semitendinosus-gracilis autografts used for ACL reconstruction.

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