

Comparison of Screw Post Fixation and Free Bone Block Interference Fixation for Anterior Cruciate Ligament Soft Tissue Grafts: Biomechanical Considerations

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Summary: Endoscopic (single-incision) anterior cruciate ligament (ACL) reconstruction with bone patellar tendon bone can usually be secured with interference screws on the femur and tibia. Infrequently, patella alta, which results in a longer tendinous component of the graft construct, can result in construct mismatch, resulting in a large portion of the tibial bone plug extruding from the tibial tunnel, requiring graft fixation with staples or a suture/screw and post technique. This study investigated the hypothesis that initial graft fixation could be enhanced if the bone plug was removed and press fit into the tibial tunnel and then secured with an interference screw in the scenario of graft construct mismatch. Initial biomechanical fixation strengths of bovine patellar tendon were compared using a screw and post suture fixation compared with a free bone plug, which was removed from the graft and sandwiched along with the soft tissue with an interference screw. Twenty-eight bovine knees were randomly divided into two groups. Graft fixation was performed with a free bone plug excised from the tibial tubercle portion of the bone tendon bone construct. Fixation was achieved with a cannulated 9-mm × 20-mm interference screw. Fixation was performed in group 2 patients with a Krackow suture of no. 5 Ticron secured over a screw and post. An Instron materials testing system was used and loading rates at 1 mm/sec until failure was performed. Statistically significant differences were noted for load to failure and stiffness ($P < .001$). Group 1 specimens' mean maximum load to failure was 669 N (range, 511 to 819 N), whereas the load to failure for group 2 patients was 374 N (range, 266 to 491 N). Group 1 stiffness was 90 N/mm (range, 50 to 122 N/m) compared with a mean stiffness of 24 N/m (range, 16 to 33 N/m) for group 2 knees. In our bovine model, free bone block interference fixation was stronger and stiffer than fixation using sutures tied over a post. This fixation method of securing a soft tissue graft with an interference screw warrants further clinical investigation and may offer an improvement to the alternative of suture/post fixation. **Key Words:** Anterior cruciate ligament—Graft fixation—Interference screws.

Numerous techniques have been popularized to reconstruct the anterior cruciate ligament (ACL)-

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deficient knee. Currently patellar tendon bone tendon bone and hamstring constructs are the most commonly used tissues for ACL reconstruction. Although the patellar tendon graft has more associated morbidity than hamstring grafts, proponents advocate its mechanical strength and the fixation that can be achieved with interference screws as major advantages that facilitate accelerated rehabilitation programs.¹⁻⁴ Single-incision endoscopic techniques have evolved from the initial double-incision arthroscopy-assisted ACL reconstruction with patellar tendon substitution. During this tran-

sition, surgeons were frequently confronted with construct tunnel mismatch, which affected the ability to perform interference screw fixation on the tibia. Changes in tibial tunnel guides and efforts to create longer, less horizontal tunnels have resulted in a marked reduction in the incidence of construct tunnel mismatch. In the authors' personal experience, an alternative form of fixation is used in fewer than 5% of our reconstructions. Patella alta with a concomitant long soft tissue component may, despite proper tunnel angle, result in graft construct-tunnel mismatch. In this situation, the surgeon must either advance the femoral graft plug within the femoral tunnel to allow for fixation on the tibial side, or secure the tibial bone plug with either staples or a screw and post form of fixation. The disadvantage of advancing the graft within the femoral socket is that the likelihood of graft laceration is increased with interference screw fixation, and that the femoral screw is buried intraosseously.

The purpose of this study was to evaluate an alternative method of fixation when confronted with a construct-tunnel mismatch that precluded interference screw fixation. As an alternative to fixation using a screw and post technique, we evaluated the fixation characteristics of removal of the bone plug from the tendon graft and press fitting into the tibial tunnel followed by placement of an interference screw.

MATERIALS AND METHODS

Twenty-eight fresh, skeletally mature bovine knees obtained from a slaughterhouse were used for testing. The knee was disarticulated and the central 10 mm of patellar tendon was harvested, still attached to the patella. A Krackow suture of no. 5 Ticon (Davis and Geck, Wayne, NJ) was placed in the distalmost 3 cm of tendon.

A guide pin was passed from the proximal medial tibial cortex, exiting on the articular surface 2 cm medial to the origin of the ACL. This guide pin was then removed and replaced with a collared pin (Arthrex, Inc., Naples, FL). A 10-mm cannulated core cutter (Arthrex) was used to create a tibial tunnel.

For group 1 specimens (free bone block interference), the harvested bone core was split longitudinally and manually fashioned into a 20-mm long wedge shape. The prepared patellar tendon was inserted into the bony tunnel, and the bone block was impacted into the tunnel in a retrograde fashion. A flexible guide pin (Arthrex) was then placed between the bone block and the bony tunnel. A 9.0-mm \times 20-mm interference screw (Arthrex) was placed over the guide pin. The bone block and the head of the interference screw were

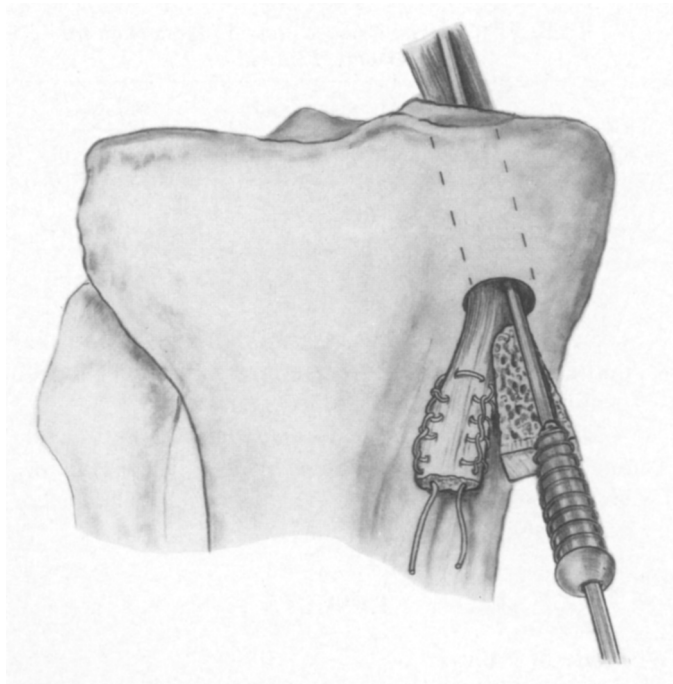


FIG 1. This diagram depicts the soft tissue, free bone block, interference screw construct fixation that was tested. A Krackow suture was placed in the patellar tendon and a 9 \times 20-mm Arthrex cannulated interference screw was placed against the free bone block. A flexible guide pin was placed to assure parallel placement.

placed flush with the medial tibial cortex (Fig 1). The sole method of fixation was from the interference screw. Sutures were used only for graft passage and not for fixation in group 1 specimens.

For group 2 specimens (sutures tied over post) a 6.5-mm \times 30-mm AO cancellous screw and flat metal washer (Synthes USA, Paoli, PA) was used as a fixation post. The screw was placed perpendicular to the long axis of the tibia 3 cm distal to the exit of the tibial tunnel on the tibial shaft. The previously placed sutures were tied around the screw and compressed the washer.

Mechanical testing was performed on an Instron materials testing machine (Instron, Corp., Canton, MA). Transverse holes were drilled in the patella, and the patella was bolted to the load cell of the material testing machine. The tibia was mounted in a custom clamping device and attached to the actuator of the materials testing machine. The orientation of the applied load was parallel to the tibial tunnel axis. The specimens were preloaded at 50 N for 3 minutes. The construct was then loaded to failure intention at a displacement rate of 1 mm/sec. The load displacement curve was recorded using an automated data acquisition system. Maximum load to failure was defined as the point on the displacement curve where the slope first clearly

TABLE 1. Maximum Loads and Stiffness Data for Groups 1 and 2

	Maximum Load	Stiffness
Group 1 (Free bone block)	669 N (range, 511-819 N)	90 N/m (range, 50-125 N/m)
Group 2 (Suture post)	374 N (range, 266-491 N)	24 N/m (range, 16-50 N/m)

decreased. Stiffness was measured as the slope of the curve in its linear region determined by fitting a tangential line to the load displacement curve.

Data analysis was performed using a two-factor analysis of variance, assuming equal variances (Microsoft Excel, Cambridge, MA). Statistical significance was established at a level of $P < .05$.

RESULTS

Mode of Failure

All specimens in group 1 failed by pullout of the patellar tendon from the interference site. In group 2, 11 of 12 specimens failed by suture breakage, and one specimen failed by suture-tendon disruption with no frank failure of the suture itself. No specimens in either group failed at sites other than those directly related to tendon fixation.

Maximum Load

The mean maximum load (Table 1) of specimens in group 1 was 669 N (range, 511 to 819 N). The mean maximum load for group 2 was 374 N (range, 266 to 491 N). This difference was statistically significant ($P < .0001$).

Stiffness

The mean stiffness (Table 1) for specimens in group 1 was 90 N/m (range, 50 to 125 N/m). The mean stiffness for group 2 was 24 N/m (range, 16 to 50 N/m). This difference was statistically significant ($P < .0001$).

DISCUSSION

Clinical applications for this form of fixation are theoretically multiple. Fulkerson⁵ has advocated the use of the quadriceps tendon as a graft source for primary and revision ACL surgery. This graft construct necessitates soft tissue fixation on one end of the graft. Fulkerson has advocated a Krackow suture with screw and post fixation. Morgan et al⁶ have proposed an "all-inside" form of fixation securing a multiple-strand hamstring graft with an antegrade-placed tibial inter-

ference screw. Multistrand hamstring is, perhaps, the least favorable situation for free bone block fixation, because uniform graft fixation would be unlikely. Allograft Achilles tendon has been commonly used for ACL or posterior cruciate ligament reconstruction and is generally secured with a screw and post or staple fixation. Steiner et al.^{5,6} have demonstrated superior fixation of hamstring grafts when the grafts are wrapped in a figure-of-eight weave and secured by two screws with washers compared with screw and post fixation. However, they have abandoned hamstring grafts and currently are using patellar tendon autograft for ACL reconstruction. Use of a free bone plug graft with interference screw fixation may allow for interference fixation at any point within the femoral or tibial tunnel. Preliminary data have suggested that juxta-articular fixation may minimize creep and elongation during the early postoperative period. Although our data cannot be extrapolated to these specific graft sources, our results merit further investigation into these specific tissues.

Our study has several important limitations. The first consideration is the selection of a bovine model. The bovine tibial metaphysis is more dense than that of the human, and the use of a bone-to-bone fixation model relies to some extent on bone density. The second limitation of this study is that our model is an in vitro study. Our results show only the strength of initial fixation and cannot necessarily be correlated to actual pullout strength as healing occurs in vivo. Another limitation is that the effects of cyclic loading on this method of graft fixation are not known. In our model, the loading is unidirectional and cannot accurately replicate the complex loading cycle that occurs with physiological stresses. Bone-to-bone healing using a free bone block with a soft tissue graft may lead to earlier long-term fixation strength, as compared with suture post fixation in which micromotion can occur between the graft material and the tibial tunnel for the entire length of the tunnel. We were more interested in evaluating the condition of soft tissue fixation. Finally, bone-to-bone healing using a free bone block has not been validated in an in vivo study.

In our study, the initial fixation strengths of a free bone plug-interference screw form of fixation for bovine patellar tendon was significantly superior to a Krackow suture secured with a screw and post form of fixation.

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