# Reverse Anterior Cruciate Ligament Reconstruction Fixation: A Biomechanical Comparison Study of Tibial Cross-Pin and Femoral Interference Screw Fixation

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**Purpose:** To evaluate the biomechanical performance of tibial cross-pin (TCP) fixation relative to femoral cross-pin (FCP), femoral interference screw (FIS), and tibial interference screw (TIS) fixation. **Methods:** We randomized 40 porcine specimens (20 tibias and 20 femurs) to TIS fixation (group 1, n = 10), FIS fixation (group 2, n = 10), TCP fixation (group 3, n = 10), or FCP fixation (group 4, n = 10) and performed biomechanical testing to compare ultimate load, stiffness, yield load, cyclic displacement, and load at 5-mm displacement. We performed cross-pin fixation of the looped end and interference screw fixation of the free ends of 9-mm-diameter bovine extensor digitorum communis tendon grafts. Graft fixation constructs were cyclically loaded and then loaded to failure in line with the tunnels. **Results:** Regarding yield load, FIS was superior to TIS (704 ± 125 N vs 504 ± 118 N, $P = .002$), TCP was superior to TIS (1,449 ± 265 N vs 504 ± 118 N, $P < .001$), and TCP was superior to FCP (1,449 ± 265 N vs 792 ± 397 N, $P < .001$). Cyclic displacement for FCP was superior to TCP. Cyclic displacement for TIS versus FIS showed no statistically significant difference (2.5 ± 1.0 mm vs 2.2 ± 0.6 mm, $P = .298$). Interference screw fixation consistently failed by graft slippage, whereas TCP fixation failed by tibial bone failure. FCP fixation failed by either femoral bone failure or failure elsewhere in the testing apparatus. **Conclusions:** Regarding yield load, TCP fixation performed biomechanically superior to the clinically proven FCP at time zero. Because TIS fixation shows the lowest yield strength, it represents the weak link, and combined TCP-FIS fixation theoretically would be biomechanically superior relative to combined FCP-TIS fixation with regard to yield load. Cyclic displacement showed a small difference in favor of FCP over TCP fixation and no difference between TIS and FIS. **Clinical Relevance:** Time-zero biomechanics of TCP fixation paired with FIS fixation show that this method of fixation can be considered a potential alternative to current practice and may pose clinical benefits in different clinical scenarios of anterior cruciate ligament reconstruction.

Successful anterior cruciate ligament (ACL) reconstructive surgery requires sufficient initial graft fixation, and many commercially available devices have shown comparable biomechanical properties and acceptable clinical outcomes.[1-3] Fixation of the loop end of a soft-tissue graft with a femoral cross-pin and the free ends with a tibial interference screw is a well-studied surgical convention in the United States. Biomechanically, femoral cross-pin fixation of the loop end of a soft-tissue graft has shown promising results regarding ultimate load, displacement, and stiffness.[2] Tibial interference screw fixation is a popular graft fixation method because of its familiarity and the ease of application; however, tibial interference screw fixation of the free ends of a soft-tissue graft has shown graft slippage at lower loads.[4] Reversing this conventional combination of femoral cross-pin and tibial interference screw fixation to tibial cross-pin and femoral interference screw fixation has been considered for ligament reconstruction. Tibial cross-pin and femoral interference screw fixation has been found useful in special cases of all-epiphyseal ACL

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reconstruction in skeletally immature patients, single-stage revision ACL reconstruction and bone grafting in patients with significant tibial bone deficiency, and double–femoral tunnel posterior cruciate ligament (PCL) reconstruction. Biomechanical evaluation of PCL tibial cross-pin fixation along anatomically separate PCL tunnel sites rather than those for the ACL has been performed.[5] Knowledge of initial fixation biomechanics for tibial cross-pin fixation may prove helpful for surgeons when faced with complicated or other unique cases of ACL reconstruction.

The purpose of this study was to evaluate the biomechanical performance of tibial cross-pin fixation relative to femoral cross-pin, femoral interference screw, and tibial interference screw fixation. We hypothesized that tibial cross-pin fixation would perform as well as the clinically proven femoral cross-pin and that femoral interference screw fixation would perform better than tibial interference screw fixation in a porcine model of ACL reconstruction.

## Methods

### Specimen Preparation

Twenty porcine femoral specimens and twenty porcine tibial specimens were potted in fiberglass in 2-inch polyvinyl chloride pipes. Prior to potting, two 1-inch drywall screws were inserted into the specimens to add stability. Bovine extensor tendons, prepared and sized to 9 mm in diameter, were used for this testing and whipstitched at their free ends for interference fixation. This method has been outlined in several studies.[6,7] Four different sample groups (n = 10 per group) were prepared according to the following specifications.

*Group 1: Tibial Interference Screw Specimens.* In group 1, grafts were individually whipstitched on both free ends using No. 2 FiberLoop (Arthrex, Naples, FL). Nine-millimeter-diameter tunnels were created in the tibias using a tibial drill guide, guide pin, and cannulated reamer. The tunnels were drilled from a point medial to the tibial tuberosity proximally toward the footprint of the native ACL, noted to be approximately 65°. The screw was inserted from a distal direction toward the articular aperture (Fig 1). Each graft was secured in place using a 9 × 25–mm titanium interference screw (AR-1390H-25; Arthrex) using an outside-in technique, capturing the graft between the screw and the anterior tibial cortex at the extra-articular opening of the tibial tunnel. The screw was seated fully in the tibial tunnel similar to a human surgical technique. The screw head was left slightly proud to achieve bicortical capture at the anterior tibial cortex when inserted at an oblique angle.

*Group 2: Femoral Interference Screw Specimens.* In group 2, grafts were individually whipstitched on both free ends using No. 2 FiberLoop. Nine-millimeter-diameter tunnels were drilled over a drill guide pin that was positioned to simulate an inside-out medial portal technique with the knee flexed at 130°. Each graft was fixed into place using a 9 × 25–mm titanium interference screw (AR-1390H-25) using an outside-in technique, capturing the graft between the screw and the lateral femoral cortex at the extra-articular opening of the femoral tunnel.

*Group 3: Tibial Cross-Pin Specimens.* In group 3, graft tunnels were prepared using methods identical to group 1. The cross-pin tunnel and insertion were facilitated using instrumentation from the Medial Portal TransFix System (Arthrex). The tunnel was drilled from a point medial to the tibial tuberosity proximally toward the footprint of the native ACL. The perpendicular tunnel was created through the intercondylar eminence using a correlating human surgical technique (Fig 2). The loop ends of the graft were fixed using a 3 × 40–mm titanium TransFix pin (Arthrex).

*Group 4: Femoral Cross-Pin Specimens.* In group 4, graft tunnels were prepared using methods identical to group 2. The cross-pin tunnel and insertion were facilitated using instrumentation from the Medial Portal TransFix System. The loop ends of the grafts were fixed using a 3 × 40–mm titanium TransFix pin.

### Mechanical Testing

Mechanical testing was performed using an Instron 8871 Axial Table Top Servohydraulic Testing System (Instron, Canton, MA), with a 5-kN load cell attached to the crosshead. The potted specimens were secured to an adjustable-angle fixture consisting of a V-block and a clamp. This fixture was positioned for pull-to-failure testing in line with the tunnel, so as to simulate worst-case loading conditions. The adjustable-angle fixture was secured to the base of the Instron machine to prevent movement during testing. The tendons of testing samples were fastened to the crosshead of the testing machine with a 30-mm gauge length to simulate a typical intra-articular graft length. The tendon loop of the interference screw samples was fixed to a pin attached to the crosshead of the material testing machine (Fig 3).

Cryo-clamps were used to fix the free graft ends on the cross-pin samples to the testing apparatus. The clamps consisted of interdigitating grooves (“s” grooves) that were cooled using standard dry ice to prevent graft slippage in the clamp (Fig 4).

The constructs were pre-cycled from 10 to 50 N at 1 Hz for 10 cycles, followed by cycling from 50 to 250 N at 1 Hz for 500 cycles. After cycling, each sample was pulled to failure at 20 mm/min.[6-8]