Biomechanical Comparison of Fixed-Loop and Adjustable-Loop Cortical Suspensory Devices for Metaphyseal Femoral-Sided Soft Tissue Graft Fixation in Anatomic Anterior Cruciate Ligament Reconstruction Using a Porcine Model

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Purpose: To compare the displacement, stiffness, and ultimate failure load of a fixed-loop cortical suspensory device with 2 adjustable-loop devices when positioned on metaphyseal bone. **Methods:** Thirty devices (10 of each device) were positioned on the metaphyseal cortex of 30 porcine femora simulating anatomic anterior cruciate ligament femoral tunnel placement. Bovine tendons were used for soft tissue grafts, and the constructs were then cycled 1,000 times and pulled to failure, measuring displacement, stiffness, and failure load. **Results:** Initial displacement, cyclic displacement, and total displacement were 2.98 mm, 2.09 mm, and 5.08 mm for the Endobutton CL (ECL), 2.82 mm, 2.27 mm, and 5.09 mm for the Tightrope (TRT), and 4.25 mm, 3.19 mm, and 7.44 mm for the adjustable-loop ToggleLoc Inline with Ziploop (TLZ), respectively. There was no difference between the ECL and the TRT on any measured outcome. Differences between the TLZ and ECL were statistically significant (initial displacement $P = .024$, cyclic displacement $P < .001$, and total displacement $P < .001$), as were those between the TLZ and TRT (initial displacement $P = .010$, cyclic displacement $P = .001$, and total displacement $P < .001$). Failure loads were 804 N, 801 N, and 682 N for the TRT, ECL, and TLZ, respectively, with no statistically significant difference. **Conclusions:** When positioned on the metaphyseal cortex, there was no difference in the biomechanical performance of the fixed-loop ECL and adjustable-loop TRT, and no lengthening of the TRTs was observed during cycling. However, the TLZ showed statistically significantly lower stiffness and more displacement during cycling with lengthening of the adjustable loop, the clinical significance of which is unknown. **Clinical Relevance:** When used for femoral-sided soft tissue graft fixation in an anatomically placed femoral tunnel, the adjustable-loop TRT was biomechanically equivalent to the fixed-loop ECL. However, the adjustable-loop TLZ showed displacement during biomechanical testing that could potentially contribute to clinical failure after anterior cruciate ligament reconstruction. However, the clinical significance was not directly tested.

Strong and rigid graft fixation is necessary for successful anterior cruciate ligament (ACL) reconstructive surgery. Adequate surgical fixation allows for early motion and rehabilitation while yielding proper biologic incorporation of the graft.

Femoral-sided fixation for soft tissue ACL grafts continues to evolve. Interference screw fixation for soft tissue grafts has been shown to allow graft slippage and have low failure loads contributing to inferior biomechanical performance.[1-4] Cortical suspensory fixation devices have provided a better biomechanical profile in several studies and have been shown to withstand the physiologic forces experienced in the early rehabilitation and ambulation phases after ACL reconstruction.[1,5-8] Newer designs of cortical suspensory devices include adjustable-loop devices that provide the additional advantages of maximizing the amount of graft in the tunnel, the retention ability after tibial fixation, and simplicity of use. A concern with adjustable-loop devices is the potential for slippage of the locking

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mechanism and lengthening of the loop resulting in a loose graft.

The functional biomechanical strength of an orthopaedic implant is dependent not only on the intrinsic mechanical properties of the implant itself, but also on the properties of the tissue in which it is implanted. In one study that compared metaphyseal and diaphyseal device placement, devices placed on diaphyseal bone performed better, with regard to ultimate failure load and cycling, than those placed on metaphyseal bone.[6] Another study compared device placement on the anterior cortex with device placement on the lateral cortex, and the authors concluded that, in a porcine model, implants on the anterior cortex perform better than those on the lateral cortex.[9] Other biomechanical studies of cortical suspensory devices have either not specified or standardized the exit point of the femoral tunnel where the cortical suspensory device sits, or were standardized to sit on diaphyseal bone.[1,3-8]

The purpose of this study was to compare the displacement, stiffness, and ultimate failure load of a fixed-loop cortical suspensory device with 2 adjustable-loop devices when positioned on metaphyseal bone. We hypothesized that there would be no difference in the amount of cyclic displacement or ultimate failure loads between the 3 cortical suspensory devices.

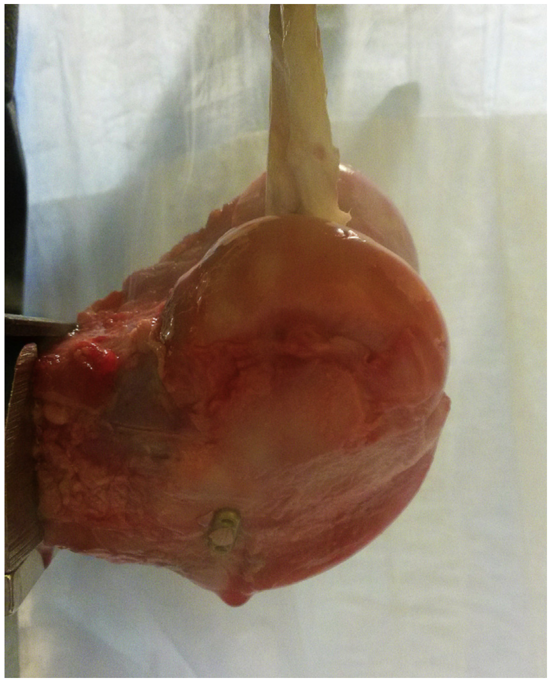

Fig 1. Cortical button position. The button is positioned on the lateral metaphyseal cortex at a standardized point located 15 mm posterior to the most proximal aspect of the lateral trochlea cartilage.

Methods

Thirty fresh frozen porcine femora (10 for each device) were obtained from Spear Products (Coopersburg, PA). The ages of the individual specimens were not provided, but they were classified as young adult. Three cortical suspensory fixation devices were tested: 1 fixed-loop device and 2 adjustable-loop devices. The fixed-loop device was the Endobutton CL (ECL; Smith & Nephew, Memphis, TN). The adjustable-loop devices were the TightRope RT (TRT; Arthrex, Naples, FL) and the ToggleLoc Inline with ZipLoop (TLZ; Biomet, Warsaw, IN). The devices were implanted and deployed according to the manufacturer's recommendations and instructions.

After the specimens were thawed, a guidewire was placed in the center of the native ACL footprint and advanced to exit the lateral femoral condyle at a standardized location. The exit point (and subsequent button placement) was standardized using an ACL tibial tunnel drill guide to exit the lateral femoral condyle metaphysis at a point located 15 mm posterior to the most proximal aspect of the lateral trochlea cartilage (Fig 1). The length of the guidewire within bone was then measured and recorded. Tunnels were drilled in this manner in an attempt to reproduce the clinical scenario of anatomic femoral tunnel placement. We then drilled an 8-mm-diameter femoral socket to a depth that would allow 20 mm of graft to be seated within the tunnel. For the adjustable-loop device, this simply required drilling to a depth of 20 mm.

For the fixed-loop device, we subtracted 20 mm from the length of the guidewire within the bone to obtain the length of the fixed loop that would allow a minimum of 20 mm of graft within the socket. We then added 6 mm—distance needed to allow the button to flip—to the length of the graft within the socket. For example, if a guidewire tunnel measured 42 mm, we selected a 20-mm loop (which would allow 22 mm of graft in the tunnel) and drilled the 8-mm-diameter socket to a depth of 28 mm (22 mm of graft plus 6 mm to allow the cortical button to pass through the cortex and flip, then engaging the cortex).

Bovine flexor tendons were cut to a length of 200 mm and thinned longitudinally to fit through an 8-mm-diameter sizing block when doubled over. At each free end, 25 mm of the graft was whipstitched. The graft was then passed through the loop of the device and doubled over. The free ends of the whipstitch suture were then tied together, and the tendon graft was placed under 20 N of longitudinal tension for 10 minutes using a graft preparation table as is routinely performed clinically in ACL reconstruction using soft tissue grafts. A mark was made on the graft 20 mm from the end that was passed through the loop, to confirm 20 mm of graft within the tunnel.

With the respective guidewire for each device positioned in the femur, the passing sutures (and tensioning