A Biomechanical Evaluation of All Inside Longitudinal Meniscal Tear Repair Devices with Matched Inside-Out Suture Repair

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Disclosures:

Introduction: Longitudinal tears of the meniscus “bucket handle tears” frequently occur at the peripheral one third of the meniscus, where the blood supply is rich, making these tears amenable to repair. They cause locking and mechanical symptoms within the joint. Surgical procedures addressing meniscus pathology are some of the most common and increasing in frequency surgeries performed by orthopedic surgeons. Due to the deleterious effects meniscectomy, there has been an evolution toward meniscal repair in hopes of preserving the force dissipation properties of the meniscus. The blind needle passage in the inside-out arthroscopic technique “the gold standard” places numerous neurovascular structures at risk. Such factors have led to the development of all-inside arthroscopic meniscus repair devices. First generation all-inside meniscal repair devices utilized non-absorbable barbed implants which frequently backed out and became loose bodies, or sat prominent and led to secondary cartilage wear in the knee joint. Current designs, such as the Smith and Nephew Ultra-Fast Fix (Smith and Nephew, Andover, MA), utilize non-absorbable anchors that are passed through the torn meniscus and sit on the joint capsule, similar to an inside-out repair, though no separate incision is made. Ceterix Orthopaedics Inc. has developed an all-side, suture based repair device that can pass suture through the torn meniscus, retrieve it within the joint, and allow the surgeon to tie arthroscopic knots without leaving anchors behind or make a separate incision (Ceterix NovoStitch, Ceterix Orthopaedics Inc., Menlo Park, CA).

Though previous studies have shown that the repair strength of the inside-out technique is significantly stronger than that of current all-inside repair devices, the design of the NovoStitch device allows for vertical, rather than horizontal, needle passage through each of the tear fragments, thereby encircling the tear and placing the stitch orthogonal to the plane of tear displacement. This study serves to compare the Ceterix NovoStitch device to inside-out vertical mattress repair and the FastFix 360 all inside repair (Smith and Nephew, Andover, MA). Previous work has shown that the FastFix created the strongest repair of all-inside devices tested. Since the NovoStitch device places suture vertically through the meniscal fragments and encircles the longitudinally oriented meniscal fibers found in the periphery where bucket handle tears occur, we hypothesized that the tears repaired with the NovoStitch device would be the strongest.

Methods: Medial and lateral fresh frozen porcine menisci were randomly assigned to one of three groups: Ceterix (Ceterix Orthopaedics Inc., Menlo Park, CA, USA) Meniscal Repair (n=18), Fast-Fix 360° (PEEK, No. 2 UltraBraid) (Smith & Nephew Endoscopy, Andover, MA) (n=18) and No. 0 Hi-Fi inside out repair (n=20). A No 11 blade was used to create a longitudinal tear via a vertical incision 3 mm from the peripheral rim beginning at the midpoint of the pars intermedia and proceeding to the anterior and the posterior horns. To create a repair with clinical relevance, the Ceterix NovoStitch™ Disposable Suture Passer was used to pass a needle across the midpoint of the pars intermedia in one pass to complete a circumferential compression stitch one centimeter apart in accordance with the manufacturer’s instructions (Figure 1a and 1d). The Ceterix NovoStitch™ Disposable Knot Pusher was used to tie each suture by Arthroscopic Revo Knot with two extra half hitches. In order to create a single-suture repair using the Fast-Fix 360° device, one vertical mattress suture was placed using Fast-Fix 360° device one centimeter apart (Figure 1c, 1f). Similarly, a strand of size 2-0 Fiber was passed one centimeter apart employing a straight Keith needle to complete an inside-out suture repair (Figure 1b and 1e) using seven total square knots to tie the suture. Provided that each repair exhibited acceptable structural integrity without malfunctioning of each device, the longitudinal tear was completed by extending the vertical incision through the anterior and posterior horns. The prepared menisci were placed in custom made clamps aligned perpendicular to the tear and mounted in an Instron 8511 (Instron Inc., Norwood, MA, USA) mechanical testing system. Cyclic loading was performed between 5 and 20 N at a frequency of 1 Hz. On each specimen, six visual markers were placed with India ink at sites adjacent to the suture repair and were grouped in pairs, with one marker placed above the suture repair and the other below. Displacement (gap formation) was recorded by measuring the distance between visual markers at a load of 5 N after cycles 0 (reference), 1, 100, 300, and 500 using a calibrated, high-resolution digital camera (PixeLINK PL-B681C, PixeLINK, Ottawa, Ontario, Canada). Displacement measurements were calculated using MATLAB (The MathWorks Inc., Natick, MA, USA) code and were assigned the vertical component of the measured distance. This software has been previously validated. Load-to-failure tests were then performed to assess the ultimate strength of the specimens.
Load-to-failure was performed at a rate of 3.15 mm.s\(^{-1}\), and the stiffness was calculated as the slope of the linear regression line approximated over the load-displacement curve between 20% and 60% of the yield load. Tissue moisture was sustained throughout the preparation and the mechanical testing by applying physiologic saline.

**Results:** All data were distributed normally. The Ceterix and size 2-0 Force Fiber inside out repairs resulted in the highest load to failure values. The stiffness values were not different between the three groups. The Ceterix, the 2-0 Force Fiber inside out and the Smith and Nephew repaired specimens demonstrated no difference in the initial cycle displacement (P=0.89). However, for cycles 100, 300, and 500, the 2-0 Force Fiber inside out repair method resulted in the highest displacement values among the three groups (P = 0.04, 0.005 and 0.002 respectively, Figure 2). No differences in displacement (gap formation) were observed between the Ceterix and Smith and Nephew repair groups at cycles 100, 300 and 500 (P = 0.65, 0.18 and 0.12 respectively). There were differences in the modes of failure observed in the repair groups. The 2-0 Force Fiber inside out repairs predominantly failed by tissue failure (n = 14, 78%) followed by suture failure (n = 3, 17%) and knot slip (n = 1, 6%); whereas the Ceterix and the Smith and Nephew repairs failed in suture failure mode only (n = 18, 100% for both groups).

**Discussion:** The vertical loop suture repair for longitudinal meniscal tears has been known to result in the biomechanically strongest repair construct. We have tested the Ceterix NovoStitch all-inside repair device that is able to create an all-inside vertical loop repair of longitudinal tears as compared to the Smith and Nephew FasT-Fix 360 all-inside repair, and the inside-out repair, as the gold standard method. While the NovoStitch and Inside/Out had similar ultimate loads to failure, the NovoStitch and Fast-Fix 360 repair exhibited much lower displacement after cyclical loading and more favorable failure mechanism in the current porcine model biomechanics study of meniscal repair.

**Significance:** Miniscal repair is one of the most common and increasing in frequency procedures in the orthopedics. Our work sheds light on the biomechanically unknown aspects of the all-inside repair procedures of the longitudinal tears “bucket handle tears” of meniscus.
Acknowledgments:
Figure 1

Figure 2