A BIOMECHANICAL ANALYSIS OF A NOVEL ARTHROSCOPIC SUTURE METHOD COMPARED TO STANDARD SUTURE KNOTS AND MATERIALS FOR ROTATOR CUFF REPAIR

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Introduction: New suture materials and techniques are continually being developed to advance arthroscopic rotator cuff repairs. Despite material and device advances, the arthroscopic suture knot remains a challenging skill to develop. A novel suture welding method involving nylon suture has been created that incorporates a unique arthroscopic handpiece that allows for suture tension and stabilization prior to suture welding via ultrasound energy applied to the suture at the tip of the handpiece. The purpose of this study was to biomechanically compare this novel suture welding method to two standard suture materials when tied with three types of arthroscopic knots.

Methods: The arthroscopic shoulder environment was simulated by using a saline filled basin with knots tied using arthroscopic instruments and cannulas. Sonic weld sutures (n=10) were created using the manufacturer’s guidelines. Weston, Roeder and Duncan knots were selected and tied with both #2 Fiberwire (FW) and #2 Ethibond (EB). Ten knots were tied for each suture group creating a total of 70 loops for testing. All loops were created over the same dowel (radius=21mm) ensuring identical suture loop circumference for each sample (132mm circumference). Samples were placed in a custom loading rig inside a servohydraulic machine (MTS858, Eden Prairie, MN). Each sample was pre-tensioned to 10N and then cyclic between 10N and 45N for 200 cycles. Patent suture loops were then loaded at 0.5mm/sec until knot compromise occurred, knot loosening or loop elongation greater than 15mm. Data for loop elongation following cyclic loading, initial stiffness, final stiffness and ultimate failure load were compared between the sonic weld and Ethibond sutures using a one-way ANOVA (p<0.05) with a Tukey’s post-hoc multiple comparisons test. Data for Ethibond and Fiberwire were analyzed with a two-way ANOVA (dependent variables: suture type and knot type) with a Tukey’s post-hoc correction test for multiple comparisons (p<0.025).

Results: The sonic weld loops had significantly greater loop elongation compared to the EB Weston knots (Figure 1) (p<0.007). There were no differences between the EB Duncan, EB Roeder or sonic sutures for loop elongation. Loop elongation was significantly lower with FW than with EB (p<0.001), without significant differences between specific FW knot types. Loop elongation was normalized to the original loop size (132mm) to assess the clinical relevance of these findings. When normalizing to the starting loop size, the EB and sonic welds experienced a relative elongation of 1.2% to 1.5%. The FW knots experienced relative loop elongation of 0.43% to 0.5%. Thus, in the clinical scenario, when total loop size might be 5-10 mm from anchor to knot, with a maximal expansion of 1.5%, loop elongation should be less than 0.15mm.

For maximum failure load, there were no differences between the various EB (Figure 2). The sonic loop demonstrated significantly lower maximum failure load when compared to the EB Weston knot only (p<0.025). When comparing the EB and FW data, the FW Roeder knot was statistically similar to all other EB knots. The Duncan and Weston FW knots were statistically similar to one another and both were significantly stronger than the EB groups (p<0.001 for all comparisons). For initial stiffness, the sonic loop demonstrated significantly lower stiffness compared to all EB knots (p<0.0125 for all comparisons) (Figure 3). There were no significant differences between the three FW knots in regards to initial stiffness. FW had significantly higher initial stiffness compared to EB (p<0.001 for all comparisons). Each loop demonstrated an increase in stiffness by more than 100% from initial to final cycle (Figure 4). The sonic loop was again statistically lower in final stiffness compared to the other EB knots (p<0.001 for all comparisons). Final loop stiffness was significantly greater in the FW than in the EB groups (p<0.001 for all comparisons), without significant differences between the three FW configurations. There were some important differences in failure modes that were observed. Every sonic weld survived cyclic loading prior to the failure test, as did every EB knot. Two of the ten FW Roeder knots had full slippage during cyclic testing and one of ten FW Weston knots experienced that same phenomenon. None of the FW Duncan knots slipped early.

Discussion: As found with previous studies evaluating EB and FW knots for arthroscopic rotator cuff repair, FW was significantly stronger in terms of ultimate failure load but also experienced some knot slippage, possibly related to the “slippery” material. Although the sonic weld had the largest increase in loop elongation compared to other EB knots, the greatest normalized magnitude of this difference was 1.5%. Normalized loop elongation data between materials and knot types are probably not important clinically. The performance of the sonic weld technique generally demonstrated a similar biomechanical performance to the standard EB suture material. It is thus important to understand both the mechanical behavior of the novel method as well as the surgical advantages it provides with elimination of tying knots, a quick and easy locking mechanism, and a low profile that eliminates high-profile sub-acromial knots. There have been recent concerns regarding the effect of construct stiffness on repair integrity as a material with a high stiffness may result in the suture cutting through the rotator cuff tendon. Thus, the question then arises as to which material provides sufficient strength and stability during the critical early rehab period while limiting potential loss of fixation within the tendon itself. Further in vitro studies using tissue fixation constructs should address this critical question.

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