Suture Performance in Standard Arthroscopic Knots — Effects of Material and Design

Introduction
Repair of damaged tissue in the shoulder, knee, and other joints is frequently performed using suture-based techniques and devices. Sliding knots play an important role in these repairs, especially when they are performed arthroscopically. Sliding knots allow the surgeon to tie knots at a distance from the repair site, restore soft tissue anatomically, and secure knots through a cannula.

The effectiveness of tissue repair depends on the strength of the construct including the anchor fixation strength, suture strength, knot security, stability of the suture loop, and how well the suture holds within the tissue.

Different suture designs, composed of new materials and made using different weave methods, are now available for use. The sliding knots currently in clinical use were developed for use with standard braided polyester suture. With the advent of new types of suture, the question arises whether the effectiveness of sliding knots differ using these new suture constructs when compared to standard braided polyester sutures.

While material strength of suture may increase its USP knot strength, this is not necessarily an indication of increased repair strength and more importantly, increased performance of arthroscopic sliding knots. The strength of the construct and consequently the repair are dependent on the security of the knot and elongation of the system (suture and loop). Therefore, while the increased material strength may minimize suture breakage due to either “sharp” devices or overzealous tightening, it may not be indicative of the repair strength.

Objective
The purpose of this study is to compare the mechanical performance of common surgical sliding knots using various sutures. Specifically, we examined the effects of material and braid design on failure mode and repair strength. In order to provide a baseline for the response of each suture under load, independent of natural variations in surgical technique, the sutures were also tested using USP and direct tensile strength methods.

Materials and Methods
The suture materials that were evaluated include ULTRABRAID™ and DURABRAID™ Sutures (Smith & Nephew), Ethibond EXCEL® Sutures (Johnson & Johnson), and FiberWire™ and TigerWire Sutures (Arthrex).

ULTRABRAID Sutures (white and co-braid), DURABRAID Sutures (white), and Ethibond EXCEL Sutures (green), all #2, were tied around two metal eyelets to simulate an anchor-tissue repair. With the advent of new types of suture, the question arises whether the effectiveness of sliding knots differ using these new suture constructs when compared to standard braided polyester sutures.

The static (non-sliding) Surgeon’s knot was used as the baseline for comparison of strength and security. The Surgeon’s knot also used three locking knots. All suture ends were cut leaving a 3 mm tail.

The loop-knot construct was pulled apart at constant rates using an electromechanical test system (Model #4411, Instron Corp., Canton MA). Failure was defined as peak load (if peak occurred at less than 3 mm) or load at 3 mm (indicating clinical failure). Our test protocol was similar to that of Lo, et al. who examined the failure properties of FiberWire. The published data from their study of FiberWire knot and loop security testing is used for comparative purposes in the current study.

US Pharmacopoeia (USP) knot and linear tensile testing was completed following protocols defined in USP 881 (Tensile Strength). The USP Official Monographs define knot tensile strength as a simple knot tied in the middle of the suture and the ends are clamped. The USP protocol is repeated without a knot for linear tensile testing. All samples were loaded to failure at a constant rate of 30 cm/min per USP standard. Peak load and elongation at peak were recorded.
Results

Figure 1 shows the variation in USP knot tensile strength between the sutures tested. In this set of experiments, ULTRABRAID™ Suture (white) is significantly stronger (p<0.05) than all other sutures tested and is 20% stronger than its nearest competitor, FiberWire™ Suture (blue). In linear tensile testing (Figure 2), the FiberWire blue suture is stronger than all other types and there is no significant difference between TigerWire (FiberWire white/black suture) and ULTRABRAID white suture.

Figures 3 and 4 illustrate arthroscopic knot strengths, organized by suture type (Figure 3) or by knot type (Figure 4). Some knot-suture combinations were not completed using every suture type. All sutures were tied with the Roeder and Tennessee Slider knot. Figure 3 illustrates the higher strength of the Surgeon’s and Roeder knots within each of the suture types. The Weston knot performs well in general but has high variability as evidenced...
by its large standard deviation. Figure 4 shows
the higher strength characteristics of the
ULTRABRAID™ Suture (both white and co-braid)
over other sutures tested and compared to
FiberWire as reported by Lo, et al.1

The test results illustrated in Figures 3 and 4
compared with data in Figure 2 indicate that
ULTRABRAID and DURABRAID™ Suture knots
maintain security close to their respective
tensile failure loads. Analysis of the failure
modes highlight the fact that these sutures
allow tighter locking of the knots and therefore
minimize suture slip, changing the failure
mode from knot slippage to suture failure. On
the other hand, FiberWire suture does not
exhibit a similarity between knot security and
tensile failure. Lo, et al. stated: “No. 2 Fiberwire
suture continues to slip despite the addition of
3 RHAPs, or with a surgeon’s knot (pg 498).”
Discussion

USP testing, combined with analysis of surgical knot strength, demonstrates the differences between suture material and braid designs. USP knot testing may highlight weaknesses of sutures, but is not a good indicator of how the knot suture construct performs in the arthroscopic surgical environment.

Standard sutures, such as DURABRAID™ and Ethibond EXCEL® are constructed from braided polyester. The new high strength sutures, ULTRABRAID® and FiberWire®, are constructed from high strength fibers (UHMW polyethylene) and may be combined with other fiber types. As expected the ultimate tensile strength of ULTRABRAID and FiberWire is significantly stronger than Ethibond EXCEL and DURABRAID. The USP knot strength highlights the fact that while tensile strength is important, a knot substantially alters the suture strength. Surgical knots affect the strength of suture constructs and the results from knot testing differ from the USP/Ultimate strength testing. Knot security is substantially higher for ULTRABRAID Sutures (both white and co-braid) than for the other sutures tested. These results are also substantially higher than published FiberWire results. This is likely due to the unique design and high strength material of the ULTRABRAID Sutures in comparison to FiberWire, DURABRAID, and Ethibond EXCEL Sutures.

Suture strength compared to knot construct strength yielded two groups. The failure strengths of ULTRABRAID, DURABRAID and Ethibond EXCEL Sutures surgical knot constructs are closer to the ultimate strengths of the suture materials. For FiberWire the ultimate strength of the suture is not reflected in the reported security of the knot construct. This indicates that failure of the construct with FiberWire is due, in part, to slippage of the knot. The dominant failure mode of ULTRABRAID, Ethibond EXCEL, and DURABRAID Sutures was suture breakage (irregardless of physiological failure). ULTRABRAID white suture reached peak load for the construct at less than 3 mm in the majority of tests. Therefore we can conclude that the security and strength of a suture construct using ULTRABRAID Suture is higher than a similar construct using FiberWire.

The elongation measurement is a reflection of the qualitative feel of the sutures. It is an objective measure of construct security and the ability to withstand loop lengthening in vivo (correlates to physiologic motion). The combination of elasticity and deformation with strength allows for more secure tissue fixation. ULTRABRAID Suture provides the surgeon with a high strength suture that combines the properties of elasticity and deformation. This allows for a pliable material that can tie sliding knots with reliable and secure soft tissue fixation.

Conclusion

Key points

- Pure tensile or USP knot testing does not provide a complete picture for performance of a suture.
- Although many factors can affect knot performance, the present study confirms that suture material and design are vitally important.
- ULTRABRAID Suture demonstrated higher strength values than other sutures for all knot types tested.
- Failure mode and the load and elongation at which failure occurs are clinically important suture attributes.
- Suture elasticity is an important characteristic affecting both knot security and handling performance.

References


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