Breaking Strength of Barbed Polypropylene Sutures

Rater-Blinded, Controlled Comparison With Nonbarbed Sutures of Various Calibers

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Objectives: To assess the strength of 2.0 barbed polypropylene suture, and, specifically, to determine the load required to break this suture, and to compare this with the strength of nonbarbed polypropylene suture.

Design: Rater-blinded, controlled trial. The individual responsible for setting up the experimental conditions was not blinded.

Setting: Biomechanics laboratory in an academic medical center.

Materials: This study did not include human subjects. Materials used included six 2.0 barbed polypropylene sutures and 3 each of 2.0, 3.0, 4.0, and 5.0 nonbarbed polypropylene sutures. Each suture was randomly selected from a different batch or box of similar sutures.

Intervention: Each suture was strung between 2 (top and bottom) cylinders and tied with a surgeon’s knot. A tensile testing device was used to apply increasing force until the suture broke. Data were acquired through an analog-to-digital board on an IBM-compatible computer using commercially available software.

Main Outcome Measures: Ultimate strength, stiffness, and elongation before suture rupture.

Results: Strength of the barbed sutures (mean [SD] ultimate strength, 39.5 [9.0] N) was intermediate between that of 2.0 (55.0 N) and 3.0 (36.4 N) nonbarbed sutures and was not significantly different from that of 3.0 nonbarbed sutures (P = .5). Barbed 2.0 polypropylene sutures differed significantly (P < .001) from each of the other types of nonbarbed sutures on measures of stiffness and elongation. Elongation of barbed sutures was closest to that of 3.0 nonbarbed sutures (P = .002). Stiffness of the barbed sutures (mean [SD], 4.7 [0.7] N/mm) was markedly in excess of that of any of the other suture types (P < .001).

Conclusions: Barbed 2.0 polypropylene sutures seem to be at least as strong as 3.0 nonbarbed polypropylene sutures. As such, barbed sutures are significantly stronger than their rated strength, which has been stated as comparable to 4.0 nonbarbed sutures. This has implications for the long-term in vivo safety of barbed sutures.

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Barbed sutures for facial lifting applications are produced by placing linear nicks along a length of nonabsorbable suture. The most commonly used substrate is a polypropylene (Prolene; Ethicon Inc, Somerville, New Jersey) core from which barbs are shaved to extend outward in a helical array. The process of creating barbs decreases the effective diameter of the suture, thus diminishing its strength. The manufacturer of the first Food and Drug Administration–approved barbed suture for facial lifting (Contour Threads; Surgical Specialties Corp, Reading, Pennsylvania) asserts that cutting barbs into thicker 2.0 polypropylene suture results in suture strength comparable to that of 4.0 nonbarbed suture. The strength of a barbed suture is of clinical importance for several reasons. First, when a surgeon is introducing, anchoring, and tying the suture into the facial subcutis, force is applied along the axis of the thread. This applied force must be sufficient so that the suture does not rupture or lose structural integrity. Second, assuming the suture is placed without incident, for several weeks thereafter, the patient must avoid motions that could cause breakage. Spontaneous facial expressions such as smiling and laughter and functional motions such as chewing food can pit powerful muscles against the strength of the suture. Until the suture is enveloped by a supportive sheath of fibrotic tissue, the suture alone is bearing the load of the lifted skin. A broken suture can result in left to right facial asymmetry and may

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siss around the implanted bars; thread migration and partial expulsion has also been reported.\textsuperscript{3} Removal of imbedded sutures can require a surgical approach that is complicated by the risk of suture breakage. Experts in the use of barbed sutures note that short- to medium-term results are usually good, but long-term safety and efficacy have yet to be established.\textsuperscript{4,5}

The purpose of this study was to objectively assess the strength of commonly used barbed sutures. Using accepted techniques for testing fiber strength, we compared barbed sutures with nonbarbed sutures of various calibers. The results of this study should help surgeons who use barbed sutures to deploy them in a manner consistent with their tensile properties.

**METHODS**

**SUTURE MATERIALS**

Experimental sutures were 6 barbed polypropylene sutures (Contour Threads; Surgical Specialties Corp). Control nonbarbed sutures were 3 sutures each from separate batches of 2.0, 3.0, 4.0, and 5.0 polypropylene (Prolene; Ethicon Inc).

**TEST EQUIPMENT**

The materials testing machine (model 1122; Instron Corp, Canton, Massachusetts) is shown in Figure 1. Data were acquired with an analog-to-digital board (DT 2821-G; Data Translation, Inc, Marlboro, Massachusetts) on an IBM-compatible computer using Global Laboratory software (Data Translation, Inc).

**EXPERIMENTAL DESIGN**

Each of 6 experimental and 12 control sutures was tested using the Instron device. Measurements were obtained for ultimate strength, stiffness, and elongation. Strength is the amount of force that can be applied to the ends of a suture before the suture breaks. Strength is measured in newtons. Before rupture, based on the intrinsic stiffness of the suture, the suture undergoes some degree of elongation, or lengthening. Stiffness is a measure of the tendency of a suture to stretch by application of increasing force before breakage. A suture that easily stretches (elongates) many millimeters is relatively less stiff than one that stretches only a few millimeters despite the application of a powerful force. Stiffness is measured in newtons per millimeter. Algebraically, stiffness is the slope of the linear portion of the load-displacement curve. Elongation is the cumulative distance a suture stretches (displacement) before breakage when force is applied. Stiffer sutures elongate relatively less, and less stiff sutures elongate more.

Before each test, the suture material was strung between 2 (top and bottom) cylinders with open jaws (Figure 2). Suture was threaded first around one cylinder, then around the other. The free ends were brought together halfway between the cylinders and attached via a surgeon’s knot tied by 1 of us (R.R.), who was not blinded as to the suture material. Machine-generated force was used by a technician (M.S.), who was blinded as to the suture material but was in the same room as the experimental apparatus, to pull on the sutures with increasing weight until the suture broke. The ability of the technician performing the experimentation to be an agent of systematic bias was further reduced in that he was unfamiliar with the caliber rating system for sutures (They were removed from the packaging and labeled with a code on an affixed sticker.) and was

In hands-on training courses on barbed suture placement for physicians that have been developed by one manufacturer (Surgical Specialties Corp), the issue of suture breakage is addressed. Specifically, users are instructed to apply firm but not spasmodic pressure to avert breakage. In addition, there are anecdotal reports of facial asymmetry caused by suture breakage in the early postplacement period, before the development of fibro-
STATISTICAL ANALYSIS

Means and standard deviations were computed for strength, stiffness, and elongation for the barbed sutures as well as for the 4 types of control sutures. Means were compared using 1-way analysis of variance (F test). Pairwise comparisons were investigated using the Bonferroni adjustment for multiple comparisons. STATA software (version 9; StataCorp LP, College Station, Texas) was used.

RESULTS

All sutures (6 experimental barbed and 12 control nonbarbed sutures) were broken with the application of increasing force. Strength, stiffness, and elongation measurements were successfully completed for all sutures (Table 1).

As expected, breaking strength varied minimally for sutures of the same caliber but differed for sutures of different thickness (Figure 3). The thickest control sutures (2.0) were the strongest and the thinnest control sutures (5.0) were the least strong, with a gradual reduction in strength associated with diminishing thickness.

Comparison of means (Table 2) of strength for the 5 types of sutures, 1 experimental (barbed) and 4 control (nonbarbed), revealed that strength differed between these categories (F = 25.43; P < .001). Similarly, stiffness (F = 54.46; P < .001) and elongation (F = 81.15; P < .001) differed across categories. Pairwise comparisons revealed that the barbed sutures differed significantly (P < .001) from each of the other types of nonbarbed sutures on measures of stiffness and elongation. Strength of the barbed sutures was intermediate between that of 2.0 and 3.0 nonbarbed sutures and not significantly different from that of 3.0 nonbarbed sutures. Elongation of barbed sutures was closest to that of 3.0 nonbarbed sutures (P = .002); stiffness of the barbed sutures was markedly in excess of any of the other suture types (P < .001). Barbed sutures were stronger and stiffer than any nonbarbed sutures but also exhibited much greater intracategory variation in strength and stiffness, as measured by standard deviation, than any of the other suture types.

Breaking strength of barbed 2.0 polypropylene sutures seems to be intermediate between that of 2.0 and 3.0 nonbarbed sutures and closer to that of 3.0 nonbarbed sutures. In addition, barbed sutures seem to be significantly stiffer than nonbarbed sutures.

These findings suggest that manufacturers of barbed sutures are conservative in their estimate that the strength of 2.0 barbed polypropylene sutures is comparable to that of 4.0 nonbarbed polypropylene sutures. Based on our data, the breaking strength of the barbed sutures is in excess of even 3.0 nonbarbed sutures. While this does not suggest that surgeons do not need to be careful in placing barbed sutures, they may be reassured that such sutures are strong

<table>
<thead>
<tr>
<th>Type</th>
<th>Caliber</th>
<th>Strength, N (SD)</th>
<th>Stiffness, N/mm (SD)</th>
<th>Elongation, mm (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barbed 2.0</td>
<td>2.0</td>
<td>39.5 (9.0)</td>
<td>4.7 (0.7)</td>
<td>9.7 (2.0)</td>
</tr>
<tr>
<td>Nonbarbed 2.0</td>
<td>2.0</td>
<td>55.0 (1.6)</td>
<td>1.9 (0.08)</td>
<td>29 (2.1)</td>
</tr>
<tr>
<td>Barbed 3.0</td>
<td>3.0</td>
<td>36.4 (2.4)</td>
<td>2.3 (0.4)</td>
<td>16 (1.8)</td>
</tr>
<tr>
<td>Nonbarbed 3.0</td>
<td>3.0</td>
<td>22.8 (0.5)</td>
<td>0.95 (0.01)</td>
<td>24 (0.7)</td>
</tr>
<tr>
<td>Barbed 4.0</td>
<td>4.0</td>
<td>12.4 (0.3)</td>
<td>0.48 (0.02)</td>
<td>25 (1.4)</td>
</tr>
<tr>
<td>Nonbarbed 4.0</td>
<td>4.0</td>
<td>27.3 (2.0)</td>
<td>1.98 (0.02)</td>
<td>30 (2.5)</td>
</tr>
<tr>
<td>Barbed 5.0</td>
<td>5.0</td>
<td>10.4 (2.0)</td>
<td>1.98 (0.02)</td>
<td>35 (2.5)</td>
</tr>
<tr>
<td>Nonbarbed 5.0</td>
<td>5.0</td>
<td>5.0 (2.0)</td>
<td>1.98 (0.02)</td>
<td>40 (2.5)</td>
</tr>
</tbody>
</table>

Table 2. Strength, Stiffness, and Elongation by Suture Type

Figure 3. Graph shows ultimate strength for each caliber and type of suture. The end of each colored line marks the point at which breakage occurred.

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and unlikely to rupture during placement, the immediate postplacement period, or during the long term.

The high level of stiffness associated with barbed sutures may be a useful adaptation to their function. While sutures used for epidermal closure need to be stretchable to accommodate tissue edema, barbed sutures placed for facial lifting may benefit from increased stiffness, which prevents rapid loss of lifting activity. The purpose of lifting sutures is not to give but to maintain tension without sagging or slipping.

This study has limitations. First, the experimental sutures and the control sutures were produced by different manufacturers. However, this was deliberate, to ensure that the most common barbed sutures were compared with the most frequently used conventional sutures. Even most surgeons who use barbed sutures made by Surgical Specialties Corp are more familiar with the tensile strength and feel of conventional sutures made by Ethicon Inc than with conventional sutures made by the manufacturer of barbed sutures.

Second, the study had a cross-sectional, ex vivo design. Specifically, we neither imbedded the sutures in live tissue nor did we wait for several months or years to test the implanted suture. It is possible that tissue reactions or the passage of time may weaken barbed sutures beyond what we observed. In defense of our design, the comparison of barbed sutures with control sutures somewhat reduces this hazard; we do not assert an absolute, unchanging strength for barbed sutures but suggest that their strength is comparable to that of certain non-barbed sutures, which are made of the same material and likely to experience similar aging and tissue effects.

Third, there was potential for variability in knot tying by the individual tying the knots (R.R.), who was able to see and feel the difference in the materials and was not blinded. The operator of the strength-measuring machinery (M.S.), however, was not apprised as to the suture used. Positioned approximately 0.9 m (3 ft) from the knotted suture, the operator is unlikely to have been able to determine suture caliber or type.

While greater numbers of individual sutures can be tested to validate the findings of this study, we found that Food and Drug Administration–approved polypropylene barbed sutures are strong and stiff. Such sutures are likely to elongate minimally during and after placement. Further, such sutures are less vulnerable to breakage than conventional 3.0 sutures, and surgeons can be reassured that rupture is unlikely even with inadvertent application of excessive force.

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Author Contributions: Dr Alam had full access to all the data in the study and takes responsibility for the integrity and the accuracy of the data analysis. Study concept and design: Rashid, Villa, and Alam. Acquisition of data: Rashid and Sartori. Analysis and interpretation of data: White, Yoo, and Alam. Drafting of the manuscript: Rashid, Sartori, and Alam. Critical revision of the manuscript for important intellectual content: White, Villa, and Yoo. Statistical analysis: Alam. Administrative, technical, and material support: Sartori. Study supervision: Rashid.

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REFERENCES

systematic reviews of narrow, patient-focused questions that are not easy to find in a textbook. For example, after a clinical encounter, a patient-oriented question might be developed, which would then be followed by a search for relevant high-quality information to answer that question. The studies that are found will be briefly and critically appraised and then applied back to the patient along with the commentary.

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Correction

Error in Byline. In the article titled “Breaking Strength of Barbed Polypropylene Sutures: Rater-Blinded, Controlled Comparison With Nonbarbed Sutures of Various Calibers,” by Rashid et al, published in the July issue of the Archives (2007;143[7]:869-872), the first author’s name should have read as follows: Rashid M. Rashid, MD, PhD.