Suture End Length as a Function of Knot Integrity

Tyler M. Muffly, MD,* Christopher Cook, DO,† Jennifer Distasio, BA,† Aaron J. Bonham, MSc,‡ and Roberta E. Blandon, MD†§

*Department of Obstetrics and Gynecology, Cleveland Clinic Foundation, Cleveland, Ohio, †Department of Obstetrics and Gynecology and ‡Office for Health Services and Public Health Outcomes Research, University of Missouri—Kansas City, Kansas City, Missouri, and §Saint Luke's Hospital of Kansas City, Kansas City, Missouri

OBJECTIVE: To evaluate tension at the failure of 3 commonly used sutures when suture ends were cut to 3 lengths.

STUDY DESIGN: Knots were tied using U.S. Pharmacopeia Size 0–0 polyglactin 910, silk, or polydioxanone sutures. The knots were tied randomly on a jig by the same surgeon. End lengths were then cut to random lengths of 0, 3, and 10 mm. We compared the individual knot strength when subjected to tensile forces via tensiometer with the point of knot failure, which was defined as untying and/or breaking of the knot.

RESULTS: Three types of suture were divided into 3 groups based on end lengths for a total of 178 knots. A logistic regression analysis showed the odds of knots coming untied were highest for polyglactin 910 (odds ratio [OR] = 33.7; 95% confidence interval [CI] = 4.1–277.1). End length also had a significant effect on knots untying, with the 0-mm knots being more likely to come untied (OR, 21.2; 95% CI, 2.9–153.0). Post hoc tests for a 3×3 analysis of variance found that silk knots failed at significantly lower tension than polydioxanone ($p < 0.001$) and polyglactin 910 ($p < 0.001$) knots.

CONCLUSIONS: The knots with an end length of 0 mm were significantly more likely to come untied than either 3- or 10-mm knots. Among all the materials, polyglactin 910 was the most prone to untying; however, it resulted in untying at a mean tension greater than the breaking point of silk. (J Surg 66: 276-280. © 2009 Association of Program Directors in Surgery. Published by Elsevier Inc. All rights reserved.)

KEYWORDS: polyglactin 910, suture end length, suture techniques, tensile strength

COMPETENCIES: Patient Care, Medical Knowledge, Practice-Based Learning

Correspondence: Inquiries to Tyler M. Muffly, MD, Center of Urogynecology and Reconstructive Pelvic Surgery, Department of Obstetrics and Gynecology, A-81, Obstetrics, Gynecology and Women's Health Institute, Cleveland Clinic, 9500 Euclid Avenue, Cleveland, OH 44195; fax: (216) 636-2620; e-mail: mufflyt@ccf.org

Supported in part by a research grant from the Saint Luke's Hospital Foundation and by donated suture material from Ethicon, Inc.

Wound dehiscence, wound separation, and hemorrhage are surgical complications attributed to suture failure. Sutures have a critical role in approximating adjacent tissues and ligating the severed ends of vessels. The knot is the weakest part of a suture. Many factors play a role in the overall integrity of a knot, including tension at failure, the diameter of the suture, the type of knot formed, the number of throws completed, and the length of the cut ends of the suture.[1]

Knot failure can occur because of breakage or slippage. All knots tend to slip to some degree and rely on the knot end lengths or suture "tails" to maintain their integrity.[2-4] Although it is imperative to provide enough suture material to allow for mechanical lengthening, an excess of suture may serve as a nidus for surgical site infection or may cause trauma. Some studies have used 3-mm suture end lengths as a point of reference; however, no studies have been conducted to provide evidence of an optimal knot end length to which suture tails should be cut.[2,5] Evidence is also lacking to show the outcomes of sutures cut at the knot, which is done for several applications. The most common situation in which knot end lengths are cut flush with the knot is when the suture is buried for a subcuticular closure.[6] Everett[7] suggested that the rigidity of suture knot end lengths causes sinus formation in some cases and thus advocated that the ends be cut flush with the knot. Monofilament knot ends have been found to cause corneal irritation in ophthalmologic surgery, and suture tail has penetrated the femoral nerve after inguinal herniorrhaphy.[8,9] Urologic surgeons also trim permanent suture close in the bladder mucosa to avoid fistulization.[10]

Currently, the best technique to maximize the full strength of sutures cut at various lengths is unknown. Each surgeon has his or her own style of suturing and cutting suture end lengths.[5] To establish an evidence-based recommendation regarding knot end length, we tested the effects of varying tail lengths on tension at failure while considering other contributory factors, such as suture material. Our goal was to establish a more precise guideline for cutting suture end lengths that maintain knot integrity and avoid associated complications.

  1931-7204/09/$30.00 doi:10.1016/j.jsurg.2009.10.003

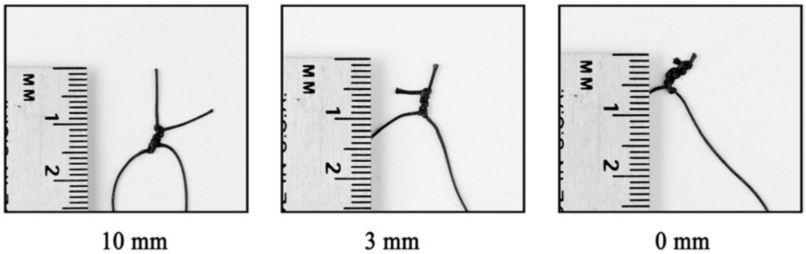

FIGURE 1. Image of 3 knot end lengths.

MATERIALS AND METHODS

Three suture materials in Size 0–0 (U.S. Pharmacopeia) were studied: absorbable multifilament polyglactin 910-dyed suture (Vicryl; Ethicon, Inc., Somerville, New Jersey), absorbable monofilament polydioxanone (PDS-II; Ethicon, Inc.), and nonabsorbable multifilament silk (Permasilk; Ethicon, Inc.). Silk was chosen because it is a historical standard for comparison with other sutures. Strand-to-strand nonidentical square knots were tied on a jig as previously described with 5 throws for multifilament and 6 throws for monofilament sutures.[5] The differing number of throws for monofilament versus multifilament suture is based on prior recommendations published in the literature.[11,12] Prior studies showed decreased friction between monofilament strands overcome by increased knotting.

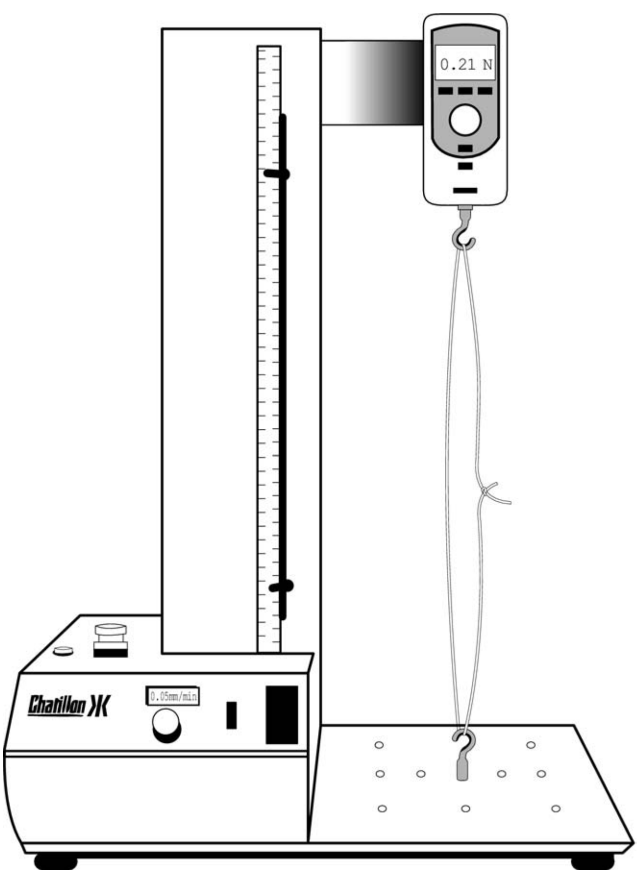

FIGURE 2. Device used for stressing suture loops.

For each suture type, knots were tied with knot end lengths cut to 0, 3 mm, or 10 mm (see Fig. 1). Randomization of suture end length was done with a computer-generated random number table. All knots were soaked in normal saline to mimic intraperitoneal conditions. Knots were tied by a single investigator over multiple sessions to avoid any variation in knot strength because of surgeon fatigue.

The tied suture was transferred to a Chatillon LTCM-100 tensiometer (Ametek, Largo, Florida). Each loop of tied suture was subjected to an elongation rate of 5 mm per minute until knot failure, and tensile force was recorded continuously (see Fig. 2). The knot failure was defined as either breakage of the suture or tail slippage past the cut ends, and tension at failure was defined as the tensile force (N) measured at breakage or slippage. To determine the effects of knot type and material on knot strength, we conducted an analysis of variance (ANOVA) with tests of main effects for both factors and the interaction between the factors.

RESULTS

The proportions of square knots with 0- versus 3- versus 10-mm knot end lengths that untied for each 0-gauge suture group are presented in Table 1. In all cases, the knots that began to unravel continued to untie completely. The loads needed to break the suture were always greater than those required for suture untying.

TABLE 1. Mean Ultimate Load in Newtons Until Knot Failure for Each Knot End Length and Material Combination

Knot End Length	Material	n	Mean (Newtons)	SD
0 mm	Polyglactin 910	24	90.4	30
	Polydioxanone	21	93.8	30.4
	Silk	22	54.3	4.3
	Total	67	79.6	30.3
3 mm	Polyglactin 910	23	103.9	18.4
	Polydioxanone	13	94.2	24.7
	Silk	17	55.8	4.8
	Total	53	86.1	27.3
10 mm	Polyglactin 910	21	103.1	16.9
	Polydioxanone	20	97.5	15.3
	Silk	17	54.7	5.9
	Total	58	87	25.1