Suture Materials, Needles, and Methods of Skin Closure: What Every Hand Surgeon Should Know

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Continuing Medical Education

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Learning Objectives

Upon completion of this CME activity, the learner will understand:

- Suture naming and classification.
- Suture needle composition and segments, and differences in needle points.
- Differences in suture materials and their characteristics and mechanical properties.

Deadline: Each examination purchased in 2021 must be completed by January 31, 2022, to be eligible for CME. A certificate will be issued upon completion of the activity. Estimated time to complete each JHS CME activity is up to one hour.

Sutures are used ubiquitously in surgery and are the most implanted materials in hand surgery. However, surgical training does not routinely include formal education on stitching materials or needles. Rather, suture familiarity is passed down by common use throughout training. We focus on a brief history and evolution of suture materials and suture needles, their material and mechanical properties, hand surgery-specific applications, other methods of skin closure

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(staples, skin glue, and adhesive strips), a cost analysis, and advances in musculoskeletal suturing, with a look toward the future. Equipped with a fundamental knowledge of suture needles and suture materials, hand surgeons will be better prepared to select the most appropriate, situation-specific tools. *(J Hand Surg Am. 2022;47(2):160−171.*

Key words History of sutures, material properties, skin closure, suture materials, suture needles.

Additional Material at jhandsurg.org

HISTORY AND EVOLUTION OF SURGICAL STITCHING

In 150 A.D., Galen of Pergamon sutured severed tendons of gladiators.[1] His writings were the first to mention catgut—twisted intestines usually made from sheep or goat—which is still used today. The etymology of the word catgut is believed to derive from the old Welsh word "kit," which means fiddle.[1] Fiddle strings were, and in some places still are, produced from these animal intestines. Eventually, "kit" gut became confused for "cat" gut.

In 1867, Joseph Lister, the father of antisepsis, determined that gut sutures could be safely left in the body if they had no bacteria on them.[1] He developed a method of sterilizing and storing catgut for future use by soaking it in carbolic acid and olive oil. He found that chromic acid, used to tan leather, would delay absorption of catgut to allow tissues a longer time to heal.[1] In 1960, sterilization by irradiation was introduced, allowing suture sterilization in the final packaging.[1]

In 1915, George F. Merson of Edinburgh, Scotland, created the first eyeless needle, patented as "Mersutures," in which a suture was inserted into the butt of the needle.[1] This style of eyeless needle became known as "swage," which reduced the tissue damage that was previously caused by pulling through double-stranded sutures. Mr Merson's company eventually became Ethicon Ltd.[1] We have summarized the historical advancements in surgical stitching in Table E1 (available online on the *Journal*'s website at www.jhandsurg.org).[1−4]

STERILIZATION AND SUTURE PACKAGING

Gamma radiation (cobalt 60) or ethylene oxide are commonly used to sterilize sutures (cold sterilization).[4] Gamma irradiation has the ability to sterilize sealed packages, with a disadvantage of degrading some absorbable sutures.[4] Natural gut and nylon sutures are safely and routinely sterilized with gamma radiation. Ethylene oxide gas is used to sterilize most other sutures, which then requires outer packaging sealing after treatment.

Suture packaging provides the sterile suture protection from microorganisms and mechanical and environmental damage, and displays detailed content information (Fig. 1). Most suture inner packaging is dry; however, gut suture inner packaging is wet with an alcohol mixture. The United States Pharmacopeia (USP) and Food and Drug Administration oversee the nomenclature, safety, and regulation of sutures.

SUTURE CLASSIFICATION

Suture naming is based on diameter (Table 1) and tensile strength. Large-diameter sutures are numbered greater than 0 (eg, 2 is larger than 1). Small-diameter sutures are labeled with 0s: the more 0s, the smaller the diameter (eg, 00 [2-0] is larger than 000 [3-0]). Metric sizes are by one-tenth of a millimeter (eg, 1 = 0.1 mm). Per USP standards, sutures of a specific name and diameter will have a minimum tensile strength.[4] Sutures of minimal tensile strength that do not abide by diameter standards are clearly labeled on the packaging. For example, by USP standards, 5-0 nylon measures between 0.1 and 0.149 mm, and a 1-knot strand has a minimum tensile strength of 3.92 N. Sutures that meet the minimum tensile strength (3.92 N) but not diameter standards are labeled "USP except for diameter" (Fig. 1).

SUTURE NEEDLES

Needles are made of martensitic stainless steels S42000, S42020, and S45500: hardened steels which contain supersaturated carbon that increases hardness and toughness and are the standard for surgical instrumentation.[4] S45500 contains nickel (7.5%−9.5%) and titanium (1.5%), whereas S42000 and S42020 have no nickel or titanium, which is a potential consideration in patients with a nickel allergy.[4]

The suture needle has 3 segments: the eye, body, and point (Fig. 2). The eye of the needle, through

FIGURE 1: Photo of suture packaging. Detailed information of the contents are displayed, including but not limited to suture diameter, suture length, needle point, needle arc, material composition, sterilization method, and expiration date.

TABLE 1. Suture and Wire Sizes

	Collagen Sutures		Synthetic Sutures		
USP Size	Metric Size	Diameter Range, mm	Metric Size	Diameter Range, mm	Wire Gauge
7	-	-	9	0.900–0.999	18
6	-	-	8	0.800–0.899	19–20
5	-	-	7	0.700–0.799	20–21
4	8	0.800–0.899	6	0.600–0.699	21–22
3	7	0.700–0.799	6	0.600–0.699	22
2	6	0.600–0.699	5	0.500–0.599	23–24
1	5	0.500–0.599	4	0.400–0.499	25–26
0	4	0.400–0.499	3.5	0.350–0.399	26–27
2-0	3.5	0.400–0.399	3	0.300–0.339	28
3-0	3	0.300–0.339	2	0.200–0.249	29–32
4-0	2	0.200–0.249	1.5	0.150–0.199	32–34
5-0	1.5	0.150–0.199	1	0.100–0.149	35–38
6-0	1	0.100–0.149	0.7	0.070–0.099	38–40
7-0	0.7	0.070–0.099	0.5	0.050–0.069	
8-0	0.5	0.050–0.069	0.4	0.040–0.049	
9-0	0.4	0.040–0.049	0.3	0.030–0.039	
10-0	-	-	0.2	0.020–0.029	

which suture material is passed, has undergone tremendous evolution (Fig. 3), from the closed and French eye needles that require the "doubling over" of a suture strand (causing significant tissue drag/trauma) to the swaged eye needle that allows a single suture strand to be placed into the hollowed-out butt of the needle.[4] The advent of lasers allowed for suture attachment onto very small needles and a shorter channel, allowing surgeons to grasp closer to the swaged end without damaging the needle.[5] Prior to laser technology, the butt was manually drilled, requiring the proximal end of the needle to be at least 0.36 mm.[4]

The body of the needle connects the eye to the point. The body shape may be triangular, round, rectangular, or trapezoidal. A "round" body may be oval to improve stiffness and handling. Ribs add grip for easier handling. A rectangular body gives the needle more rigidity and helps minimize needle bending and twisting. Needle shapes include straight; curved 1/4, 3/8, 1/2, or 5/8 circles (Fig. 4); ski; compound curve; and side-cutting.

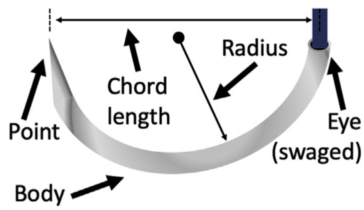

FIGURE 2: The anatomy of a needle, with the needle point for piercing tissue; body that may be modified (with ribs, for example, to improve grip); and eye that attaches the suture strand to the needle. The needle radius and chord length are also depicted.

COMMON NEEDLE POINTS: TAPERED AND TRIANGULAR

Needle points are commonly represented by a 2- or 3-letter code (Table 2). Triangular configurations are reverse cutting or cutting (Fig. 5). Cutting needles contain a triangular apex facing the arc, with an increased cutout risk, whereas reverse cutting needles' triangular apex faces away from the arc, decreasing the cutout risk (Fig. 6). Various combinations of points and bodies exist (eg, taper-cut needles have triangular points with round/oval bodies).

Tapered needles have round bodies that taper into a sharp point without cutting edges (Fig. 5C). Tapered needles cause the least tissue trauma as the needle point pierces, and the round body gently stretches the tissue as it advances. The tissue elastically recoils, leaving behind a small-profile hole. The taper ratio is the ratio of the length of the tapered portion to its diameter. Greater taper ratios minimize resistance of needle penetration through tissue.[5] Manufacturers alter taper ratios for clinical, financial, and proprietary purposes. Labeling of needle points may be confusing: for clarity, look at the packaging (Fig. 1).

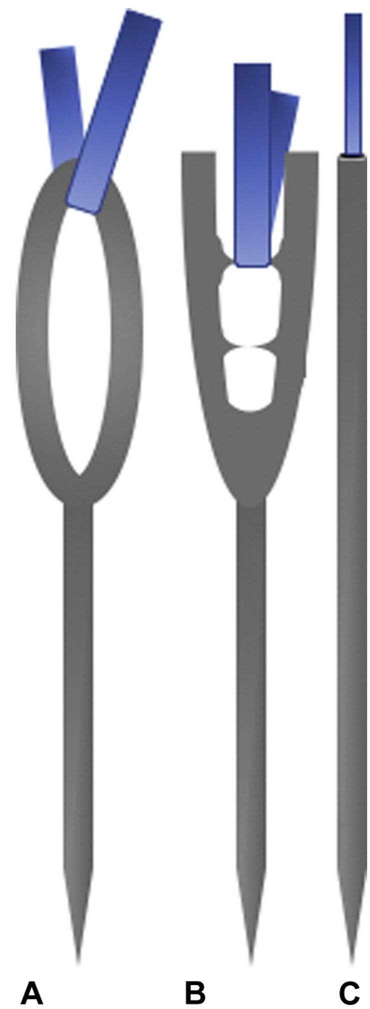

FIGURE 3: Needle eyes. **A** Initially, a closed eye similar to the common sewing needle was the standard. The suture strand was doubled over, in a time-consuming and soft tissue trauma-promoting process, dragging the doubled-over suture and creating a greater hole in its wake. **B** A variation of the closed needle was the French eye needle, which facilitated suture strand loading, but maintained the doubled-over suture strand configuration. **C** Subsequently, the swaged needle was invented, connecting the needle and suture in a single, continuous unit, which was made possible by a hole drilled at the end of a suture needle, with an inserted suture strand that is crimped to secure it in place.

SUTURE MATERIAL CHARACTERISTICS

Material properties

Versions of natural (eg, catgut, silk) and synthetic sutures may be absorbable or nonabsorbable.[6] Natural sutures have favorable handling properties with primary disadvantages that include substantial tissue reaction and, with catgut sutures, the potential for prion disease (bovine spongiform encephalopathy).[6] Synthetic sutures contain long strands of polymers, whose combinations contribute to tensile strength. Generally, synthetic sutures retain tensile strength longer than natural sutures secondary to a decreased tissue reaction. Examples of nonabsorbable synthetic sutures are nylon and Prolene (polypropylene). Examples of absorbable synthetic sutures are PDS (polydioxanone) and Vicryl (glycolide and lactide).

Absorption

Natural absorbable sutures break down by enzymatic degradation through proteases released by phagocytes during the inflammatory phase of wound healing.[6] Synthetic absorbable sutures undergo hydrolysis into monomers.[6] Specific combinations of monomers provide unique properties for synthetic sutures. For example, adding glycolide provides stiffness and

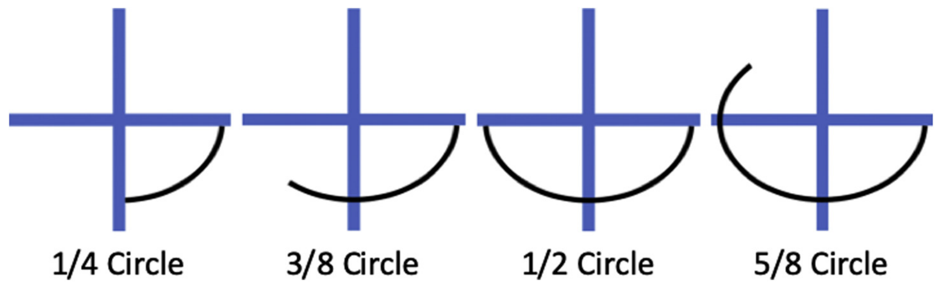

FIGURE 4: Needle radius of curvature. Curved needles provide a predictable path through tissue. Curves of 1/4 of a circle are commonly used in eye surgery and microsurgery. The most common curves are 3/8 and 1/2 of a circle for general use on skin, fascia, and tendons. The 1/2−circle curves are designed for use in small spaces, requiring more pronation/supination of the wrist. Curves of 5/8 of a circle are used for deeper tissues in confined spaces, such as in the pelvis.

TABLE 2. Suture Codes and Definitions With Point and Body Characteristics Commonly Used in Hand Surgery

Code	Definition	Symbol	Point	Needle Body Arc
BV	Blood vessel	⊙	Taper	3/8
CT; MO; RB; SH	Circle taper; mayo; renal bypass (artery); small half (circle)	⊙	Taper	1/2
ST	Straight taper	⊙	Taper	Straight
UR	Urology	⊙	Taper	5/8
FS	For skin	▼	Reverse cutting	3/8
OS	Orthopedic surgery	▼	Reverse cutting	1/2
P; PS	Plastic; plastic surgery	▼	Reverse cutting	3/8; 1/2
V	Taper-cut surgical needle	▼	Reverse cutting	Straight; 1/4; 3/8; 1/2
KS; TS	Keith straight; tendon straight	▼	cutting	Straight

increases hydrolysis. Vicryl sutures (90% glycolide and 10% lactide) absorb faster than PDS (polydioxanone) and newer sutures with high concentrations of lactide.[7] Tensile strength diminishes as sutures resorb. Nonabsorbable sutures maintain tensile strength much longer than absorbable sutures. The suture material is retained long after tensile strength is lost. Absorption may occur over days to weeks, depending on the suture properties and patient condition (Table 3).[4]

Surface architecture influences: monofilament, polyfilament (braided), and barbed suture

Monofilament sutures (eg, nylon, Monocryl) contain smooth surfaces, resulting in less tissue trauma, less capillarity, and a lower infection risk from harboring bacteria.[6] Monofilaments may stretch and require careful knotting, as the smooth surfaces allow for insecure knots. Suture microfractures may occur with careless needle-holder handling, predisposing them to early failure.

The surface areas of polyfilament sutures (eg, Ethibond, Vicryl) are thousands of times greater than those of monofilament sutures.[6] Braided sutures afford easy handling and favorable knotting properties, where the between-braid friction provides knot security.[8] However, braided sutures have greater tissue drag (resistance through soft tissue), causing increased tissue trauma. Furthermore, an increased surface area allows fluid pooling in crevices between filaments, potentially harboring and protecting bacteria from phagocytic cells.[6,8] Additionally, braided sutures incite greater inflammation than monofilament sutures.[8]

Barbed monofilament sutures obviate knot tying. There has been concern over the irregular surface of barbed sutures creating small crevices for bacteria to possibly form biofilm.[9] However, studies have demonstrated that barbed sutures do not increase

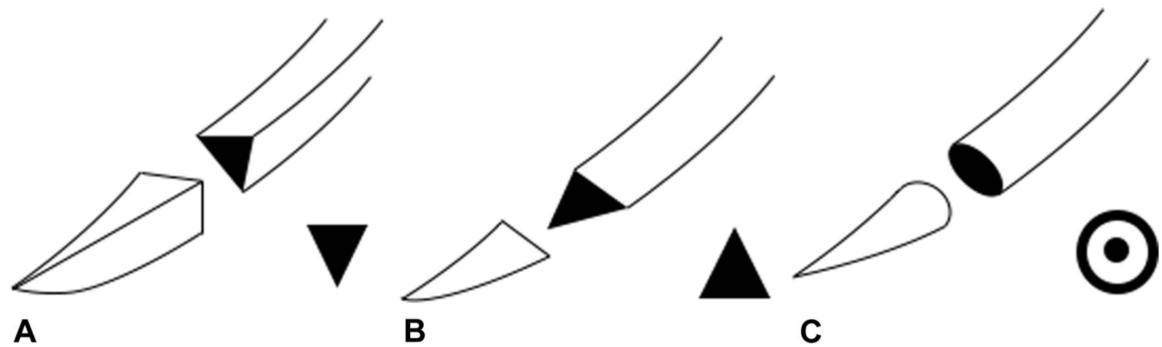

FIGURE 5: Needle points. Common needle points are **A** cutting, **B** reverse cutting, and **C** tapered. **A** In hand surgery, cutting needles are seldom used. **B** Reverse cutting needles are most commonly used for the skin, fascia, tendons, and/or nerves. **C** Tapered needles are most commonly used for blood vessels, dura, and/or nerves.

surgical site infection risks when compared to traditional suture types in clean wounds, and have even demonstrated lower risks of surgical site infection compared to traditional braided interrupted subcutaneous sutures.[9,10] While a barbed suture package may be more expensive, the overall cost and surgical time are generally lower with barbed sutures.[9–11]

Tissue reactivity

The Sewell scoring system is used to formally grade tissue reactivity, which includes the number of cells per high-powered field and the width of inflammation, weighted by the types of inflammatory cells present (eg, neutrophils are scored higher than lymphocytes).[12] Natural sutures incite a greater inflammatory response than synthetic sutures.[8] Of the nonabsorbable sutures, silk has the most reactivity; of the absorbable sutures, catgut has the most reactivity (Table 4).[4,13]

Antimicrobial agents

Sutures coated with antimicrobials were designed to prevent bacterial and fungal colonization and thus decrease the risk of surgical site infections, particularly against common pathogens, including *Staphylococcus aureus* (both methicillin-sensitive and methicillin-resistant), *Staphylococcus epidermidis*, *Escherichia coli*, and *Klebsiella pneumonia*.[2] Triclosan is the most prevalent antimicrobial suture-coating agent. Commonly used in hand sanitizers and cleaners, triclosan is biocompatible, is nontoxic, has a broad spectrum without resistance, and does not interfere with wound healing.[2] A large meta-analysis demonstrated that triclosan-coated sutures significantly reduced the 30-day risk of surgical site infections by 27%, with similar findings across other systematic reviews of randomized controlled trials.[14–16] Ethicon adds

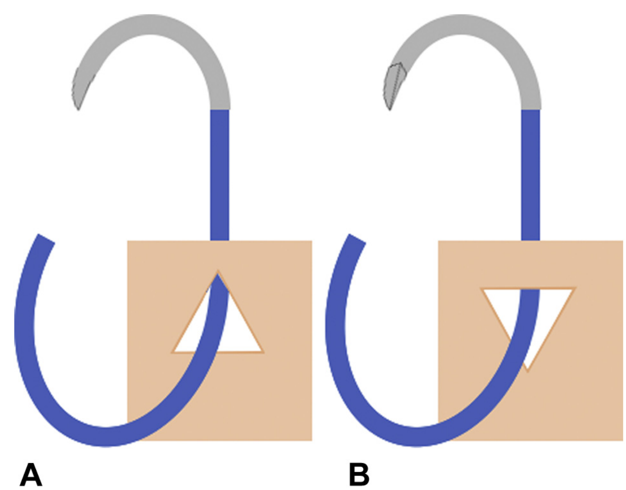

FIGURE 6: Cutting needle points and tissue trauma. Illustration of **A** a cutting needle's path and **B** a reverse cutting needle's path through tissue. **A** Note that the cutting needle leaves behind a hole in the tissue with the apex of the triangular hole close to the edge of the wound, allowing for easier tear-through. **B** In the reverse cutting needle illustration, the base of the triangle is closest to the edge of the wound, allowing for a greater contact area between the tissue and suture material, therefore decreasing the risk of tear-through.

"PLUS" to the name of a suture to denote antimicrobial coating (eg, Vicryl PLUS).

Mechanical properties

Hand surgeons must choose appropriate suture needles and suture materials for various tissues based on a number of factors: for example, size (Table 5) and tissue type (Table 6). Other aspects of selecting 1 suture over another may depend on the mechanical properties of the tissues being repaired, as well as the mechanical properties of the sutures themselves. For instance, one must consider the surgical application

TABLE 3. A List of Accelerants to Degradation of Absorbable Sutures

Acidic or basic environment
Dilute milieu (lower salt concentrations)
High tension
Gamma irradiation
Many free radicals
Infection
Elevated temperature
Protein deficiencies
Synovial fluid

TABLE 4. Tissue Reactivity of Absorbable Sutures, In Order From Most Reactive (1) to Least Reactive (4)

1. Catgut (purified bovine/sheep collagen)
2. Polyglycolic acid (Vicryl)
3. Polytrimethylene carbonate (Maxon)
3. Polydioxanone (PDS)
4. Poliglecaprone (Monocryl)
4. Polyglytone (Caprosyn)

(Table 7), knot security, ease of handling, predictability of mechanical performance, tissue drag, capillarity, tissue reaction, and even cost.

Tensile strength

Tensile strength, measured by a tensiometer, is the weight necessary to break a suture divided by the cross-sectional area of the suture. The relationship is nonlinear, as the cross-sectional area is πr^2. Consequently, a large-diameter suture has a greater tensile strength, and studies evaluating strengths must compare sutures of equal diameters.[17] A knotted suture has one-third the tensile strength of an unknotted suture. Therefore, clinically relevant studies measure the effective tensile strength: the strengths of looped and knotted sutures.

Breaking strength retention

Breaking strength retention is a measure of the percentage of a suture's original tensile strength at different time points. The majority of strength is lost within the first 60 days.[17] The maximum breaking strength begins to decline immediately after placement due to mechanical stress and tissue fluid influences.[17] The suture is weakened by handling and other factors (Table 3).[17] Dyes such as gentian violet added to a suture provide better visualization and slightly longer strength retention compared to undyed counterparts.[2] Although large-diameter sutures have higher tensile strengths than smaller-diameter sutures, they lose relative strength at similar rates. However, the initial tensile strength is an important factor. Poliglecaprone (Monocryl), for example, retains adequate tensile strength for the first week of healing due to a high initial tensile strength.

TABLE 5. Common Applications Based on Suture Size

USP Size	Diameter, mm	Common Applications
10-0 to 8-0	0.02−0.04	Microsurgery (eg, small vessels in the hand)
7-0 to 6-0	0.05−0.07	Epitendinous repair, large neurovascular structures
5-0 to 4-0	0.1−0.15	Large neurovascular structures, skin closure
3-0 to 2-0	0.2−0.3	Skin closure, vessel ligation, small tendons, small joint capsule
0−1	0.35−0.4	Fascia, muscle, large joint capsule
2−5	0.5−0.7	Large tendon repair
6−7	0.8−0.9	Surgical steel−cerclage wiring of fractures

Bending stiffness, memory, and plasticity

Bending stiffness measures how a material handles: the force required to bend sutures to desired angles. Large-diameter sutures have more stiffness than small-diameter sutures. Monocryl and PDS II have the least stiffness and best handling properties.[4]

Memory, as a result of bending stiffness and correlated with elasticity, is the suture's ability to return to its prior configuration (form and length) after being stretched.[6,8] Often, memory refers to the retention of its coiled shape from packaging.[6] Excessive memory is undesirable for handling and knotting. However, high memory is beneficial in edematous tissues, where sutures should accommodate swelling and retain their configurations.[8]

Plasticity is the ability to take on a new shape through applied stress.[6] Plasticity is the reciprocal of memory (high plasticity = low memory), and therefore sutures with high plasticity often have limited memory and are able to remain in whichever shape the are placed. Plasticity allows for better handling and knotting (eg, silk has high plasticity and nearly

TABLE 6. Suture Material and Needle Options Based on Surgical Tissue Type*

Tissue	Suture	Needle	Example(s)	Notes
Bone	Perm, braided	▼	Tenodesis with bone tunnels (Fiberwire)	Alternate: suture anchors with permanent sutures
Fascia	Abs (superficial); Perm (deep)	⊙	Extensor retinaculum (2-0 Vicryl)	Tapered needles decrease tissue damage and cutout
Muscle	Perm, synthetic, braided	⊙/▼	Muscle repair of forearm (3-0 Ethibond)	Goal: decrease scarring with perm or synthetic suture, which can affect contractility
Tendon	Choice 1: Perm, braided Choice 2: Perm, monofilament Choice 3 (rare): Abs	⊙/▼	Zone II flexor tendon repair—braided core (3-0 Fiberwire); monofilament epitendinous (6-0 Prolene)	Tapered needles = less trauma. Reverse cutting needles = ease of penetration
Nerve	Perm, monofilament	⊙	Ulnar nerve repair at elbow (8-0 nylon)	Goal: decrease scarring or neuroma risk
Blood vessels	Perm, monofilament	⊙	Microvascular repair (9-0 or 10-0 nylon)	Avoid cutting needles to minimize trauma or hole size

Abs, absorbable; Perm, permanent.
⊙ denotes tapered needle point.
▼ denotes reverse cutting needle point.

no memory, and therefore excellent handling and knotting properties). However, highly plastic materials may take on unwanted shapes, such as kinking of steel sutures, making suturing and tying more difficult.

Capillarity

Capillarity refers to the ability to transport fluid through a measured length of suture in a specific time frame.[4] High capillarity may increase the infection risk due to the propensity to absorb bacteria-contaminated fluid. The ability for a suture to potentiate infection can be measured by contaminating a suture with a known quantity of bacteria and measuring the bacterial growth after several days. Monofilaments have less capillarity and much lower bacterial growth than braided sutures.[4] Therefore, some surgeons avoid braided sutures in deep wounds at risk for contamination.

Tissue drag

Tissue drag is the force required to overcome resistance of the suture's pull through tissue. Lower drag results in less tissue damage. Suture coating (eg, beeswax, silicone, polytetrafluoroethylene, or stearates) may minimize the coefficient of friction and tissue drag, thereby decreasing capillarity and the associated infection risk.[2] A monofilament suture has a smooth surface with lower tissue drag than a braided or twisted suture.

SKIN CLOSURE ALTERNATIVES: STAPLES, SKIN GLUE, AND ADHESIVE STRIPS

Staples

Skin staples, used for rapid skin closure, are composed of stainless steel. They have the greatest tensile strength of all skin closure materials and are thus used in high-tension wounds (eg, scalp). They have low reactivity and a similar infection risk to those of most sutures.[18] Studies demonstrate equivalent cosmetic outcomes when compared to nylon sutures, largely due to the excellent wound eversion that staples provide.[18,19] While staples are generally costlier than sutures, the rapidity with which wounds are closed using staples may be more cost-effective than suturing.[18,19]

Skin glue

Skin glue is a convenient alternative to sutures. Application is rapid and simple: it is applied to opposed wound edges (usually after buried sutures) in liquid form and solidifies, forming a chemical bond with the skin. Skin glue protects wounds from microbes and the environment. The glue dries rapidly

TABLE 7. Characteristics and Applications of Absorbable Sutures Commonly Used in Hand Surgery

Suture	Category	Material	Strength Retention, d	Application
Plain catgut	Natural	Purified bovine or sheep collagen	5–7	General soft tissue approximation
Chromic catgut	Natural	Purified bovine or sheep collagen coated with chromic salts	21–28	General soft tissue approximation
Fast catgut	Natural	Purified bovine or sheep collagen heat treated	3–5	Dermis
Vicryl	Synthetic	Polyglycolic acid	60% at 21	General soft tissue
Vicryl rapide	Synthetic	Polyglycolic acid, heat treated	50% at 5	Superficial skin
Vicryl PLUS	Synthetic	Polyglycolic acid, triclosan-coated	50% at 21	General soft tissue
Dexon	Synthetic	Polyglycolic acid	50% at 15	General soft tissue
Monocryl	Synthetic	Poliglecaprone	50% at 7	Skin closure
PDS	Synthetic	Polydioxanone	4–0; 36% at 42 3–0; 60% at 42	General soft tissue, where swelling is expected
PDS II	Synthetic	Polydioxanone, heat treated	50% at 28	General soft tissue, where swelling is expected
Maxon	Synthetic	Polytrimethylene carbonate	50% at 28	General soft tissue

and lasts approximately 1–2 weeks until it peels off.[20]

Currently available skin glues include octyl cyanoacrylate (Dermabond), butylcyanoacrylate (LiquiBand), and N-butyl-2-cyanoacrylate (GlueSeal). GlueSeal is available in multiuse packaging. The butyl formations are more rigid and dry more quickly than octyl formations of cyanoacrylates (30 seconds compared with 60 seconds).[20]

Advantages of skin glue over sutures include the speed and ease of application, liberty of showering without the burden of dressing applications, decreased infection risk, and lack of a need for suture removal. Additionally, the allergic contact dermatitis risk is minimal, allowing for application on patients with latex or adhesive allergies. The primary disadvantage is a poor cosmetic appearance if the skin glue seeps into a wound with improperly everted skin edges or without direct apposition, which may cause a wide-appearing scar. Therefore, meticulous subcutaneous closure is paramount. There is no significant cosmetic benefit to either wound closure method.[21–23] Although it is outside the scope of a discussion on skin closure, it is worth mentioning that skin glue is commonly used in hand surgery for nail bed injuries. Octyl cyanoacrylate (Dermabond) nail bed repairs allow for a more expeditious procedure with similar cosmetic and functional results as compared to suture repair.[24]

Adhesive strips

Adhesive strips (eg, Steri-Strips, 3M) are another option for wound closure. Most commonly, strips are placed on the skin surface perpendicular to the incision following subcutaneous suture placement.[25] Adhesive strips last 1–2 weeks, with a longer durability if the surrounding environment is dry, has low mobility, and has minimal edema/swelling, and if a liquid adhesive is applied prior to strip application.[2] However, adhesive strips have not demonstrated improved scar cosmetics compared to subcuticular sutures without adhesive strips.[25] Common liquid adhesives include gum mastic (Mastisol) and benzoin tincture. Gum mastic liquid provides superior adhesive qualities with lower risks for contact dermatitis and associated skin discoloration.[26] The common complications of adhesive strips include allergic contact dermatitis and blistering from skin shear tension in the setting of edema.

Alternative uses for adhesive strips are largely in the role of skin reinforcement. For example, the strips may be applied perpendicular or parallel to the incision and simple sutures passed through the strip

TABLE 8. Cost of Absorbable Sutures Commonly Used in Hand Surgery

Absorbable Suture	Price, USD	Suture Size, USP	Needle Point	Company	Composition
Chromic gut	$4.77	5-0	P-3	Ethicon	Intestinal beef serosa or sheep submucosa with chromic salts
Plain gut	$4.67	5-0	P-3	Ethicon	Intestinal beef serosa or sheep submucosa
Monocryl	$4.52	3-0	PS-2	Ethicon	Polyglicaprone 25
Monocryl PLUS	$5.06	3-0	PS-2	Ethicon	Polyglicaprone 25 and triclosan
Vicryl	$1.32	3-0	RB-1	Ethicon	Polyglactin 910
Vicryl PLUS	$1.52	3-0	RB-1	Ethicon	Polyglactin 910 and triclosan
Vicryl	$3.09	4-0	PS-2	Ethicon	Polyglactin 910
Vicryl RAPIDE	$5.21	4-0	PS-2	Ethicon	Polyglactin 910
Stratafix Spiral Monocryl PLUS	$29.99	3-0	PS-1	Ethicon	Polyglicaprone 25 and triclosan
Stratafix Spiral	$21.44	4-0	FS-2	Ethicon	Polyglycolic acid and polycaprolactone

USD, US dollar.

TABLE 9. Cost of Nonabsorbable Sutures Commonly Used in Hand Surgery*

Nonabsorbable Suture	Price, USD	Suture Size, USP	Needle Point	Company	Composition
Prolene	$4.44	4-0	PS-2	Ethicon	Polypropylene
Perma-Hand Slk	$1.29	4-0	FS-2	Ethicon	Silk
Perma-Hand Slk	$2.76	4-0	PS-2	Ethicon	Silk
Supramid (looped)	$13.50	4-0	Taper	S Jackson	Polyamide
Supramid (double arm)	$12.50	4-0	P-1, P-3	S Jackson	Polyamide
Ethibond	$1.30	2-0	CT-2	Ethicon	High-molecular-weight, long-chain polyesters
Ethibond	$3.09	4-0	PS-2	Ethicon	High-molecular-weight, long-chain polyesters
Fiberwire	$22.00	4-0	Taper	Arthrex	Long-chain UHMWPE core, polyester, and UHMWPE jacket
Fiberloop	$50.00	4-0	Taper	Arthrex	Long-chain UHMWPE core, polyester, and UHMWPE jacket
Gore-tex	$24.67	2-0	CV-3	WL Gore	Polypropylene

UHMWPE, ultra-high-molecular-weight polyester; USD, US dollar.

and the skin, reinforcing the strength of the skin, with the primary advantage of the parallel method being even tensile forces along the length of the incision.

COST ANALYSIS

The costs associated with absorbable and nonabsorbable sutures commonly used in hand surgery are detailed in Tables 8 and 9, respectively. The price data were obtained from a single institution's actual purchases in the year 2019. While no definitive conclusions may be drawn, as suture prices vary across institutions, this analysis offers some insight into the matter. Both the suture material and needle must be considered in a cost analysis. Proprietary needle points, such as the reverse cutting "Plastic Surgery" point, are markedly more expensive than a generic reverse cutting "For Skin" needle point. Tables 8 and 9 indicate that hand surgery needles cost approximately twice as much as For Skin needles and that barbed sutures are approximately 5 times the price of their nonbarbed counterparts (ie, Stratafix versus Monocryl, respectively). Additionally, Arthrex sutures are significantly more expensive than most other sutures shown in Table 8 and Table 9. Interestingly, antibiotic-coated (triclosan) sutures are marginally more expensive (10%−14%) than their noncoated counterparts: an expense that should be evaluated against the cost of managing a surgical site infection.

WHAT'S NEXT: TECHNOLOGICAL ADVANCES AND FUTURE DEVELOPMENTS IN MUSCULOSKELETAL SUTURING

Advances in suture materials are trending toward augmented tissue healing: providing mechanical strength during the healing process, with the ultimate goal of replacing the suture material with newly formed tissue. The suture material may be tailored to specific tissue types (by disease and age) to promote maximal regeneration.[27] At the fiber level, sutures may be manufactured on a submicron scale to mimic the native collagen fibril architecture, which varies with health and age. On the surface, biophysical cues, such as grooves, patterned dots, and ridges, may be microfabricated to mimic natural structures present in the matrix to stimulate native cell populations to secrete, deposit, and remodel native extracellular matrices.[28] Another advancement includes suture porosity for cell-driven repair through a scaffold effect based on pore size, balanced against tensile strength. Additional developments may include drug-eluting sutures for controlled release of chemicals through a biodegradable polymer system, such as antibiotics, local anesthetics for pain relief, and anti-inflammatories.[28] Finally, sutures coated with mesenchymal stem cells or gene-activating protein sequences may promote and expedite tissue healing.[28]

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JOURNAL CME QUESTIONS

Suture Materials, Needles, and Methods of Skin Closure: What Every Hand Surgeon Should Know

1. Which of the following needle designs increases the risk of suture tear-through skin?

a. Conventional cutting (triangular apex facing inward, toward the arc)
b. Reverse cutting (triangular apex facing outward, away from the arc)
c. Tapered
d. Taper cutting

2. Which of the following does not accelerate the degradation of absorbable suture?

a. High tension
b. Infection
c. Elevated temperature
d. Synovial fluid
e. Addition of dye (eg, gentian violet)

3. Which of the following absorbable sutures has the greatest tissue reactivity?

a. Poliglecaprone (Monocryl, Ethicon Inc)
b. Polyglycolic acid (Vicryl, Ethicon Inc)
c. Catgut (purified bovine / sheep collagen)
d. Polydioxanone (PDS, Ethicon Inc)
e. Polytrimethylene carbonate (Maxon, Covidien)

4. Triclosan is an antimicrobial agent that is used to coat sutures to decrease the risk of infection. Which of the following is true regarding Triclosan?

a. It is toxic to human tissue.
b. It is only effective against Gram-positive organisms.
c. It is effective against methicillin resistant staphylococcus aureus (MRSA).
d. It interferes with wound healing.

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TABLE E1. Brief History of Sutures*

Date	Region	Category	Advancement(s)
~500 B.C.	India	Suture material properties	Susruta used sutures of flax, hemp, bark, fiber, or hair
150	Roman Empire	Tendon repair	Galen of Pergamon sutured severed tendons of gladiators • First to mention catgut
1867	England	Sterilization; suture material properties	Joseph Lister, the father of antisepsis: • Realized sterile sutures may be safely implanted • Developed a method for sterilizing and storing catgut by soaking in mixture of carbolic acid and olive oil • Realized chromic acid, used to tan leather, delays absorption of catgut to allow tissues a longer time to heal
1890	Germany	Needle material properties	Metallurgist Adolf Martens invented martensitic steel: hardened steel crystalline structure of supersaturated carbon that is high in hardness and toughness
1906	USA	Standardization	FDA founded: uses USP standards. Additionally, ensures public safety through its own sterility and packaging standards
1937	USA	Standardization	USP (founded: 1820), established standards for suture naming, diameter, tensile strength, labeling, and sterility
1915	Scotland	Suture material properties	George Merson invented eyeless needle • "Swaged needle": suture inserted into butt of needle • Reduced tissue damage: single versus double strand • Mr Merson's company became Ethicon Ltd
1956	USA	Mechanical properties	Unidirectional barbed sutures invented
1960	Scotland	Sterilization	Gamma irradiation allows sterilization in final packaging
1972	USA	Mechanical properties	Bidirectional barbed sutures invented

FDA, Food and Drug Administration; USA, United States of America.