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Tying Knots Between Wound Closure Materials

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Abstract

Wounds caused either intentionally during procedures or secondarily due to trauma need to be approximated to achieve primary closure. There are many methods to approximate wound edges, with the use of sutures being the most popular and common. Other methods such as staples, tissue adhesives, and strips also exist. This article aims to review the primary tools that are used for wound closure taking their materials into consideration as well.

Keywords: Sutures, wound closure, staples, tissue adhesives, strips, barbed sutures

Introduction

With a historical background reaching the times of ancient Egypt, sutures have been the most popular method of wound closure not only in plastic surgery but also in other fields of medicine.[1] Choosing the right material depending on the features of the wound has critical importance since it directly affects the process of wound healing and the aesthetic result. Hence, many properties should be kept in mind while determining the type of suture to be used such as knot security, tensile strength, size limits, visibility, absorbability, and the composition of the suture as these factors can directly influence the quality of wound healing, time for suture removal, the potential for infection, and other complications.

This study aims to review the basic concepts and properties of suture materials that are commonly used in daily practice and recent developments in the field of wound closure.

Sutures

Every suture material has its own advantages and disadvantages, and most of the time, there is no definitive option for the suture to be used. The decision is made by the physician not only based on the objective properties of the material but also on the previous experience of the physician with the material and what the physician expects from the suture in addition to the wound and patient factors. However, it is still important to know the basic differences between the subgroups of the suture materials. For instance, although knots are more easily tied with the multifilament sutures because of the higher friction coefficient, there is an increased risk of infection and granuloma formation with these sutures, as they do not glide through the tissue as smooth as monofilament sutures. On the other hand, compared to their monofilament counterparts, these sutures are easy to handle and result in better knot security. They are, therefore, more commonly used to close dermis and subcutaneous tissue in order to reduce wound tension, while skin closure is frequently done with monofilament non-absorbable sutures because of the lower incidence of inflammatory response and their easy application. Basic information regarding a standard surgical suture package and some of the available options we currently have are demonstrated in Figure 1.

The sutures may be broadly categorized as absorbable and non-absorbable, as well as mono- or multifilament. Absorbable sutures may either be hydrolytically or proteolytically degraded, and because of their absorbability, depending on the material, they may lose half of their tensile strength in less than a month. On the other hand, non-absorbable sutures are eventually encapsulated secondary to a cell-mediated immune response around them. The time required to maintain tension is a major factor while determining the type of suture, and generally rapidly absorbing sutures are used to close layers with minimal tension for a short time. For prolonged intervals, permanent sutures are used to provide necessary strength for instances such as tendon, ligament, or nerve repair, and even bone anchoring. Absorbable sutures are mainly used to maintain strength for around 4-6 weeks and are generally used to close fascia and subcutaneous tissue. Sheik Ali et al[2] reviewed the previous studies investigating the rate of postoperative complications, wound dehiscence, and surgical site infections based on the absorbability of the suture material and concluded that there is no statistically significant difference. Relatively new meta-analyses also revealed that there is no significant difference between absorbable and non-absorbable suture materials in scar appearance and wound-related complications including infection and dehiscence.[3] It was concluded, however, that differences exist during the evaluation of the outcomes which necessitates a closer look between individual materials which will be provided in the upcoming sections of this review.

Absorbable Suture Materials

To date, available absorbable sutures include surgical gut, collagen, polyglytone 6211, poliglecaprone 25, glycomer 631, glycolide/lactide copolymers, polyglycolic acid, polyglyconate, and polydioxanone. These sutures mostly lose their tensile strength within 60 days of their use and are used primarily for dermal and subcutaneous closure. Natural absorbable sutures include surgical plain and chromic gut. Surgical gut sutures are produced from purified strands of collagen obtained from sheep or beef intestinal serosa and submucosa. Other collagen sutures also exist, which

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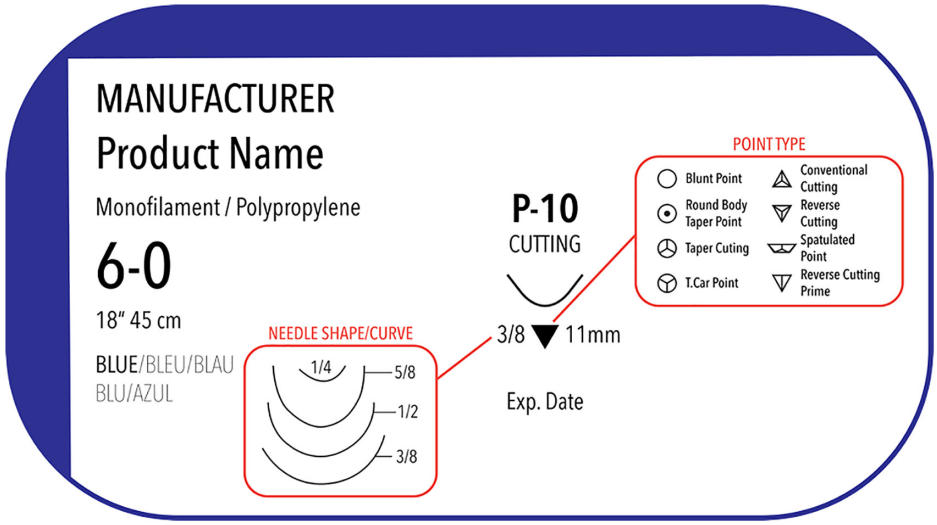

Figure 1. A standard suture package. On the left hand side, manufacturer, product's name, the material description, suture gauge with United States Pharmacopeia (USP) system, length in inches and centimeters, and color are listed. On the right hand side, information regarding the surgical needle including the profile, curve, and its point type is shown.

are also derived from collagen from cattle tendons and are still used especially in ocular surgery with better tensile strength. These monofilaments are composed of 97%-98% pure collagen. In general, these sutures are rapidly absorbed and lose 50% of their tensile strength in approximately 1 week. When bathed in chrome, the chromic gut is formed and its tensile strength lasts longer, with 50% of its strength lost in 2-3 weeks and absorption time is longer than the plain gut.[4] It causes less tissue reaction than the plain gut but more than the synthetic absorbable sutures. It is however important to note that plain and chromic gut are no longer in use in our country and European Union following the bovine spongiform encephalopathy crisis.

Synthetic absorbable sutures result in less intense tissue reactions than natural ones. Polyglactin 910 was the first one to be introduced in this field and is a braided suture, with 50% of its tensile strength remaining after approximately 3 weeks. A modified version of polyglactin 910, coated polyglactin 910, was then produced for better handling and knot security in addition to the antibacterial effect with triclosan, an agent that inhibits colonization of some, but not all, gram-negative and -positive bacteria. It loses 75% of its tensile strength after 2 weeks, is absorbed minimally until the 40th day of application, and is then eliminated between 56th and 70th days. Compared to polyglactin 910, its coated version was associated with lower pain scores on postoperative day 1 but was otherwise similar in means of intraoperative handling and wound complications.[5] Rapidly absorbed versions of polyglactin 910 also exist, which are primarily used for skin closure. Since removal is unnecessary, these sutures are particularly important for lacerations that will not be uncovered for a while or are located in sensitive areas and for the pediatric population.[4] Alinasab & Per-Olle Haraldsson reported similar complication rates and cosmetic outcomes with polypropylene and rapidly absorbing polyglactin 910 in the closing of transcolumellar incision in rhinoplasty, which does not require any visits for painful suture removal.[6] When compared to nylon and stainless steel, polyglactin 910 was found to be associated with a higher rate of wound infections and granuloma formation in patients who underwent median nerve release surgery with comparable results for erythema and hypertrophy.[7] Furthermore, polyglactin 910 elicited a higher rate of inflammation compared to polypropylene in a similar study.[8] Another study comparing rapid polyglactin 910 to polypropylene sutures in skin closure of head and neck defects revealed similar results of scarring and inflammation for both sutures.[9] In plastic surgery, polyglactin is mostly used to approximate wound edges with dermal and subcuticular sutures, and rapidly absorbed counterparts are commonly used for skin closure. Both types of polyglactin, whether rapidly absorbing or not, were however used successfully in oculoplastic surgery with comparable results.[10] In contrast, in a pediatric population undergoing elective hand surgery, patients who underwent skin closure with regular polyglactin 910 exhibited a higher frequency of wound-related complications compared to rapidly absorbed polyglactin 910, which was attributed to the difference in the absorption rate by the authors.[11] Additionally, they are a crucial element in procedures breaching the mucosa, such as cleft palate and orthodontic surgeries. Rapidly absorbed polyglactin 910 is particularly important for cleft lip surgery, if used, the non-absorbable alternatives such as polypropylene and polyamide require additional hospital stay and intervention under general anesthesia or sedation for removal, which is by-passed if rapidly absorbed polyglactin 910 is used, with a comparable cosmetic outcome and without an increased risk of complications.[12]

Polyglycolic acid is a polymer of glycolic acid, a multifilament, and braided suture which causes minimal tissue reaction due to its hydrolytic elimination.[13] Mono-multifilament and coated–uncoated products of polyglycolic acid exist and its primary use is in subcutaneous closure. Poliglecaprone 25 sutures are monofilament sutures used primarily in subcuticular closure that is easy to handle. Their initial high tensile strength diminishes in 2 weeks. In a randomized–controlled trial studying the outcomes of subcutaneous sutures with poliglecaprone versus polyglactin 910, poliglecaprone 25 was superior to polyglactin 910 with a lower rate of wound complications, with overall cosmetic outcomes being similar.[14] Closure with poliglecaprone 25 resulted in a similar cosmetic outcome with polypropylene sutures in patients undergoing Mohs surgery and in both groups no complications such as infection, dehiscence, and hematoma were observed.[15] These sutures are widely used in our current practice, especially during continuous subcuticular skin closure of aesthetic reduction mammoplasty or

abdominoplasty surgeries. The use of poliglecaprone 25 in breast reduction patients resulted in a lower incidence of hypertrophic scar formation, wound reaction, and a smaller scar size than rapid polyglactin 910.[16]

Polydioxanone is another monofilament suture material that retains 50% of its tensile strength even 42 days after implantation and is completely absorbed by 180 days following application. It causes a little inflammatory reaction.[17] Polydioxanone was compared to polyglactin 910 in its use in intradermal sutures of facial rhytidectomy, and no statistically significant difference was found in the means of erythema, scar spread, hypertrophic scar, infection, and induration. In the long term, cosmetic outcome was evaluated and was found to be better in the polydioxanone group. Hypertrophic scars were more common, but wound dehiscence, inflammation, and reaction were less frequent, although no statistical significance was demonstrated.[18] We perform suturing with polydioxanone in rhinoplasty surgeries, especially during tip plasty where 5/0 sutures are commonly preferred. These sutures are also feasible to use while performing plication during abdominoplasty surgeries or closing the deep layers of the abdominal wall. Polyglyconate is another monofilament absorbable material that is smoother to handle with a longer-lasting tensile strength. Polyglytone, a monofilament absorbable material, loses its tensile strength faster but demonstrates comparable cosmetic outcomes and similar rates of wound complications with a lower risk of extrusion than poliglecaprone 25.[19]

Non-absorbable Suture Materials

Silk, nylon, polypropylene, polybutester, polyester, and surgical steel are examples of non-absorbable sutures. Non-absorbable sutures that are organic are produced from natural resources including cotton, linen, and silk with silk being the most popular. Silk is a multifilament of natural fibers with high resistance. It is low cost and is easy to use. However, infection and inflammation are more commonly observed.

Polyamide sutures are used commonly in microsurgery as well as skin closure in aesthetic surgery because of their excellent tensile strength. They however tend to recover to their initial state—a concept called memory—which requires a higher number of knots while using these materials. Both mono- and multifilament products of polyamide sutures exist. Polyamide sutures have a wide area of use, including facial aesthetic surgery and microsurgery. In our practice, they are most frequently used during microsurgery including nerve repairs and microvascular anastomoses. Differences in the rates of wound healing complications and cosmetic outcomes of lacerations repaired with nylon and polyglactin 910 were studied and the results of both of the categories were statistically insignificant.[20] Outcomes of upper eyelid blepharoplasty patients were compared in another study according to the use of surgical gut and nylon, and no difference in cosmetic outcome and pain was observed.[21]

Polypropylene is one of the most frequently used sutures in daily practice. It has wide use in many fields of surgery, from skin closure to microsurgery, including vascular anastomoses. Its durable tensile strength and resistance to degradation make it an ideal choice for these purposes. Polypropylene causes minimal tissue reaction and therefore is a suitable option for facial lacerations and trauma for cosmetic purposes. Polytetrafluoroethylene (PTFE) is another type of monofilament sutures. An important feature of this material is that it causes less tissue reaction than other materials. Despite its use in orthopedic, ocular, or dental surgery, we do not routinely use PTFE sutures in our practice.

Stainless steel surgical sutures are another example of non-absorbable suture materials, and they are used primarily in fields where prolonged retention of tensile strength and good knot security is required, such as orthopedic and cardiovascular surgery and neurosurgery. They may be monofilament or braided, and their disadvantages include less flexibility, difficult handling, and possibility of fracture and kinking.[17]

Barbed Sutures

Barbed sutures are a relatively new technology with the first product approved by the Food and Drug Administration in 2002.[4] They can be manufactured from materials such as polydioxanone, poliglecaprone 25, glycomer 631, polyglyconate, or non-absorbing materials such as nylon or polypropylene. Exo- and endobarbed versions of these sutures exist with the latter one requiring higher diameters to provide the same tensile strength as the smooth sutures, since their diameters decrease along the suture because of the barbs.[22] For example, 2-0 polypropylene suture with barbs has a tensile strength similar to a 3-0 polypropylene non-barbed suture. Exobarbed sutures do not have this feature, since the barbs are attached to a core filament, which has the same diameter throughout the suture. Since they are applied in a continuous fashion and require no loops, they do not cause the typical ischemic foci of the suture loops, and because of the continuous application, they distribute the tension equally along the incision. These features make barbed suture use especially feasible in areas where the skin is very fragile, or when the wound edges are relatively more difficult to approximate with regular smooth sutures. In addition, continuous application without the need for loops decreases the closure time. However, barbed sutures are still more expensive than their smooth counterparts, but decreased operation time overall leads to a general decrease in the cost of the procedure.[23] They have become a topic of interest since their introduction to the market and have been incorporated in many fields of surgery, including gastrointestinal surgery, urology, orthopedics and traumatology, obstetrics and gynecology, and plastic, reconstructive, and aesthetic surgery. The literature has been continuously updated on the uses of these sutures in plastic surgery, where new techniques of its use in procedures such as face lifting, platysmoplasty, brow lifting, canthopexy, mastopexy, augmentation and reduction mammoplasty, rhinoplasty, and abdominoplasty have been described and reviewed.[24,25]

In a large study comparing smooth and barbed sutures, complication rates were similar and closure time was significantly shorter with barbed sutures. Minor and major complication rates were observed to be similar to the smooth sutures.[26] Another study concluded that in addition to operation time, barbed sutures decreased the number of suture packets used during a procedure, decreased the rate of needle stick events, and had improved cosmesis compared to deep polyglyconate monofilament sutures in elective aesthetic operations.[27] Moreover, in patients undergoing breast reconstruction surgeries with deep, inferior epigastric perforator flaps were less likely to have a donor-site wound-related complication if the closure was performed with barbed sutures.[28] When used in tie-over dressings, barbed sutures provided a higher pressure on the graft and a reduction in the operation duration.[29]

Topical Adhesives and Surgical Strips

Topical adhesives that can be used in daily practice include ones that are composed of butyl cyanoacrylate and octyl cyanoacrylate. Advantages include the ability to shower immediately after the procedure, no concern for track scars, reduced rate of dehiscence, and easy and rapid application with the cosmetic results remaining

statistically insignificant from wound closure with sutures. In addition, they are suitable to use for the pediatric population and for patients with lower pain thresholds since they require no anesthesia, also no procedures afterward such as suture removal. Octyl cyanoacrylate was found to be superior to butyl cyanoacrylate for longer incisions and has a better breaking strength. Disadvantages include drying time, more difficult access beneath the wound in case of complications, and infrequent incidence of allergic contact dermatitis.[4] Moreover, they cannot be used for wounds with high tension and that are located over joints. Cosmetic outcome is better when the adhesives are used in conjunction with dermal sutures and it is cosmetically comparable to subcuticular continuous suture with 2-0 polyglycolic acid and found to be superior to metal staples and nylon sutures.[30] Another study showed that comparable cosmetic results can be obtained with adhesives and subcuticular polyglycolic acid which are superior to closure with metal staples and vertical mattress sutures. However, subcuticular closure resulted in less dehiscence and inflammation.[31] Maartense et al[32] reported a significantly lower number of actions taken and similar cosmetic outcomes with octyl cyanoacrylate compared to poliglecaprone 25 and adhesive tapes but a higher cost per procedure in closure of trocar wounds after laparoscopic surgeries. Another study comparing cosmetic outcomes of elective surgeries where either nylon subcuticular sutures or octyl cyanoacrylate was used showed better results with tissue adhesives.[33]

Strips are similar in their use to topical adhesives. In addition to their individual use, they may be applied to wounds approximated with sutures; however, no statistically significant benefit has been reported with this use.[34] Their advantages and disadvantages are similar to the ones of topical adhesives. Strips were found to be associated with less erythema and edema without any difference in cosmetic outcome and pain compared to absorbable subcuticular sutures in a study; however, a price gap exists between these two methods of wound closure.[35] A meta-analysis comparing other wound closure methods to adhesive strips concluded there is no statistically significant difference in cosmetic outcome and infectious complications.[36]

Staples

Staples are also a method of closure, especially useful in areas of high tension. They have been shown to reduce the time for wound closure by approximately 3-4 folds. In a study where nylon sutures were compared to closure with staples, no significant difference in cosmetic outcome and complications was found, and the use of staples was associated with a shorter time needed to close the incisions.[37] Another study also demonstrated that closure with staples does not change the rate of complications compared to closure with sutures.[38] Abdus-Salam et al demonstrated in their study on cesarean section patients that closure with subcuticular polyglycolic acid sutures does not have any additional benefits to closure with staples in terms of scar cosmesis.

Staples, however, require more time to be removed in addition to the pain experienced during removal. Therefore, absorbable dermal staples have been introduced and they are easy to use, pose a lower risk of infection, provide a comparable cosmetic outcome, and do not require removal.[39] Closure with either subcuticular staples or sutures did not result in a statistically significant difference in inflammation, hypertrophy, and swelling, and the use of staples was associated with a shorter operation time.[40] Although the use of metal staples and absorbable subcuticular staples have no effect on the cosmetic outcome, better-wound eversion, less crusting and erythema, and better patient comfort can be obtained with the subcuticular staples.

There are many ways to close an incision or laceration, where one can use sutures, staples, adhesives, strips, and even other ways which are beyond the scope of this article. Surgeons and physicians who are involved in laceration management should have a basic opinion on the materials that are used to close wounds.

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