Roberts: Clinical Procedures in Emergency Medicine, 5th ed.

CHAPTER 35 – Methods of Wound Closure

Richard L. Lammers

Once the decision to close a wound has been made, the clinician must select the closure technique best suited for the location and configuration of the wound. The most commonly used techniques include use of tape, tissue adhesive, metal staples, and sutures. All traumatic wounds should be cleaned, and wounds containing devitalized tissue should be débrided before closure (see Chapter 34, Principles of Wound Management).

Self-inflicted wounds can present to the emergency department (ED) with a vague or inaccurate history. Characteristic self-mutilation patterns are depicted in Figure 35–1 . No specific treatment is required other than recognizing these patterns of injury

Figure 35–1 *A–C,* These patients had minor lacerations and were brought to the emergency department (ED) simply for tetanus prophylaxis or for other vague or unrelated reasons. Obviously, these are classic self-inflicted wounds, representative of serious underlying psychiatric issues, requiring further evaluation. *D,* These cigarette burns are also self-inflicted, but the patient initially stated that she burned them on grease while cooking.

WOUND TAPE

Surgical tape strips are now routinely used to close simple wounds. Tape strips can be applied by health care personnel in many settings, including EDs, operating rooms, clinics, and first aid stations. Advantages include ease of application, reduced need for local anesthesia, more evenly distributed wound tension, no residual suture marks, minimal skin reaction, no need for suture removal, superiority for some grafts and flaps, and suitability for use under plaster casts. One main advantage of wound tapes is their greater resistance to wound infection compared with standard sutures and wound staples. [1] [2] [3] [4]

Background and Tape Comparisons

Currently, there are several brands of tapes with differing porosity, flexibility, strength, and configuration. Steri-Strips (3M Corporation, St. Paul, MN) are microporous tapes with ribbed backing. They are porous to air and water, and the ribbed backing provides extra strength. Cover-

Strips (Beiersdorf, South Norwalk, CT) are woven in texture and have a high degree of porosity. They allow not only air and water but also wound exudates to pass through the tape. Shur-Strip (Deknatel, Inc, Floral Park, NY) is a nonwoven microporous tape. Clearon (Ethicon, Inc, Somerville, NJ) is a synthetic plastic tape whose backing contains longitudinal parallel serrations to permit gas and fluid permeability. An iodoform-impregnated Steri-Strip (3M Corporation) is intended to further retard infection without sensitization to iodine.[3] Other tape products include Curi-Strip (Kendall, Boston), Nichi-Strip (Nichiban Co., Ltd, Tokyo), Cicagraf (Smith & Nephew, London), and Suture Strip (Genetic Laboratories, St. Paul, MN).

Scientific studies of wound closure tapes provide some comparisons of products. Koehn[5] showed that the Steri-Strip tapes maintained adhesiveness about 50% longer than Clearon tape. Rodeheaver and coworkers[6] compared Shur-Strip, Steri-Strip, and Clearon tape in terms of breaking strength, elongation, shear adhesion, and air porosity. The tapes were tested in both dry and wet conditions. The Steri-Strip tape was found to have about twice the breaking strength of the other two tapes in both dry and wet conditions; there was minimal loss of strength in all tapes when wetted. The Shur-Strip tapes showed approximately two to three times the elongation of the other tapes at the breaking point, whether dry or wet. Shear adhesion (amount of force required to dislodge the tape when a load is applied in the place of contact) was slightly better for the Shur-Strip tape than for the Steri-Strip tape and approximately 50% better than for the Clearon tape. Of these three wound tapes, the investigators considered Shur-Strips to be superior for wound closure.

One comprehensive study of wound tapes compared Curi-Strip, Steri-Strip, Nichi-Strip, Cicagraf, Suture Strip, and Suture Strip Plus.[7] All tapes were 12 mm wide except for Nichi-Strip, which was 15 mm. Each tape was compared for breaking strength, elongation under stress, air porosity, and adhesiveness. Curi-Strip, Cicagraf, and Steri-Strip exhibited equivalent dry breaking strengths. However, when wet (a condition that can occur in the clinical setting), Cicagraf outperformed all tapes. All of the tested tapes had similar elongation-under-stress profiles with the exception of Suture Strip Plus. This tape did not resist elongation under low or high forces. Excessive elongation may allow wound dehiscence. Nichi-Strip was the most porous to air, and Cicagraf was almost vapor-impermeable. Nichi-Strip and Curi-Strip had the best adherence to untreated skin. When the skin was treated with tincture of benzoin, however, Steri-Strip dramatically outperformed all other products. When all study parameters were considered, Nichi-Strip, Curi-Strip, and Steri-Strip achieved the highest overall performance rankings.

Indications

The primary indication for tape closure is a superficial straight laceration under little tension. If necessary, tension can be reduced by placing deep closures. Areas particularly suited for tape closure are the forehead, chin, malar eminence, thorax, and nonjoint areas of the extremities. Tape also may be preferred for wounds in anxious children when suture placement is not essential. In young children who are likely to remove tapes, tape closures must be protected with an overlying gauze bandage.

In experimental wounds inoculated with *Staphylococcus aureus*, tape-closed wounds resisted infection better than wounds closed with nylon sutures.[2] Tape closures work well under plaster casts when superficial suture removal would be delayed. Tape closures effectively hold flaps and grafts in place, particularly over fingers, the flat areas of the extremities, and the trunk (Fig. 35–2).[3] [4] Wounds on the pretibial area are difficult to close, especially in the elderly because of tissue atrophy. Wound tapes provide an alternative to suture closure in this situation. Tape closures can be applied to wounds after early suture removal, particularly on the face, to maintain wound edge approximation while reducing the chance of permanent suture mark scarring. Finally, because of the minimal skin tension created by tapes, they can be used on skin that has been compromised by vascular insufficiency or altered by prolonged use of steroids.

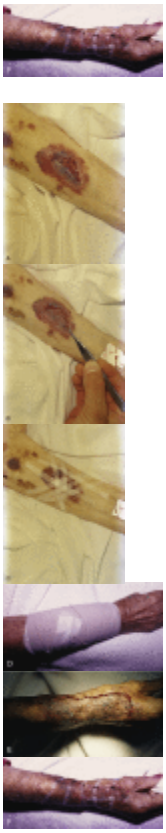

Figure 35–2 *A,* A skin avulsion in the elderly following minor trauma is an ideal wound to close with closure tapes, as such injuries cannot be closed with sutures. The goal is to provide approximation of the avulsed skin and apply pressure to avoid skin flap movement or fluid accumulation under the avulsion. Tissue glue can augment this procedure. An elderly woman who was on steroids had extremely thin skin and suffered a skin avulsion that could not be replaced with sutures. *B,* The skin edges are uncurled, stretched, and anatomically replaced. *C,* The wound should heal when closure tapes keep the skin in place. Tissue glue (Dermabond®) was also dabbed on various parts of the edges, allowing for fluid egress. *D,* A compression dressing, such as an elastic bandage or a Dome paste (Unna) boot dressing, can be applied to minimize flap movement and decrease fluid buildup under the flap. *E* and *F,* Large avulsion replaced with Steri-Strips and tissue glue. Tape should be placed in a semicircular or spiral pattern on digits to avoid constriction. *G,* After suturing this proximal-based flap, Steri-Strips are applied under a tourniquet, compressing the flap to arrest flap motion and lessen fluid buildup.

Contraindications

Tape closures have disadvantages. Tape does not work well on wounds under significant tension or on wounds that are irregular, on concave surfaces, or in areas of marked tissue laxity. In many cases, tape does not provide satisfactory wound edge apposition without concurrent underlying deep closures. Tape does not stick well to naturally moist areas, such as in the axilla, the palms of the hands, the soles of the feet, and the perineum. Tape also has difficulty adhering to wounds that will have secretions, copious exudates, or persistent bleeding. They are of little value on lax and intertriginous skin, in the scalp, and in other areas with high concentration of hair follicles. Tape strips are also at risk for premature removal by young children.

Tapes should not be tightly placed circumferentially around digits because they have insufficient ability to stretch or lengthen. If placed circumferentially, the natural wound edema of an injured digit can make the tape act like a constricting band, which can lead to ischemia and possible necrosis of the digit. Semicircular or spiral placement techniques should be used if digits are to be taped.

Equipment

For a simple tape closure, the required equipment includes forceps and tape of the proper size.

Most taping can be done in the ED with $\frac{1}{4}$ -x 3-inch strips. In wounds larger than 4 cm, however, $\frac{1}{2}$ -inch-wide strips provide greater strength. Most companies manufacture strips up to 1 inch wide and up to 4 inches long.

Procedure

Proper wound preparation, irrigation, débridement, and hemostasis must precede tape closures. Fine hair may be cut short or shaved, and the area of the tape application is thoroughly dried to ensure proper adhesion. Attempting to apply tapes to a wet area or over a wound that is slowly oozing blood will usually result in failure of the tapes to stick to the skin. On fingers, tapes can be applied to a wound that is kept dry by a tourniquet temporarily placed at the base of the finger (see Fig. 35–2*G*).

The technique of applying tapes is shown in Figure 35–3 . After the wound has been dried, a liquid adhesive such as tincture of benzoin or Mastisol can be applied to the skin adjacent to the wound to increase tape adhesion.[2] All tapes come in presterilized packages and can be opened directly onto the operating field. Tapes should be handled with gloved hands. With backing still attached, tapes are cut to the desired length or long enough to allow for approximately 2 to 3 cm of overlap on each side of the wound. After the end tab is removed, the tape is gently removed from its backing with forceps by pulling straight back. Do not pull to the side, because the tape will curl and will be difficult to apply to the wound. One half of the tape is securely placed at the midportion of the wound. The opposite wound edge is gently but firmly apposed to its counterpart. The second half of the tape is then applied. The wound edges should be as close together as possible and at equal height to prevent the development of a linear, pitted scar. Additional tapes are applied by bisecting the remainder of the wound. A sufficient number of tape strips should be placed so that the wound is completely apposed without totally covering the entire length of the wound. Finally, additional cross tapes are placed to add support and prevent blistering caused by unsupported tape ends.[1]

Figure 35–3 Proper technique for application of tapes for skin closure. *A,* After wound preparation (and placement of deep closures, if needed), dry the skin thoroughly at least 2 inches around the wound. Failure to dry the skin and failure to obtain perfect hemostasis are common causes of failure of tapes to stick to the skin. *B,* If desired, apply a thin coating of tincture of benzoin around the wound to enhance tape adhesiveness. Benzoin should not enter the eye, as it causes pain if it seeps into an open wound. *C,* Cut the tapes to the desired length before removing the backing. *D,* The tapes are attached to a card with perforated tabs on both ends. Gently peel the end tab from the tapes. *E,* Use forceps to peel the tape off the card backing. Pull directly backward, not to the side. *F,* Place half of the first tape at the midportion of the wound; secure firmly in place. *G,* Gently but firmly appose the opposite side of the wound, using the free hand or forceps. If an assistant is not available, the operator can approximate the wound edges. The tape should be applied by bisecting the wound until the wound is closed satisfactorily. *H,* Wound margins are completely apposed without totally occluding the wound. *I,* Additional supporting tapes are placed approximately 2.5 cm from the wound and parallel to the wound direction. Taping in this manner prevents the skin blistering that may occur at tape ends.

Taped wounds are not covered with occlusive dressings. Adhesive bandages (e.g., Band-Aids) and other impermeable dressings promote excessive moisture, which can lead to premature separation of tape strips from the wound. An adhesive bandage also may adhere to the tapes, pulling them off the skin at the time of the dressing change. Tapes may remain in place for approximately 2 weeks or longer, if necessary. The patient can be allowed to clean the taped laceration gently with a slightly moist, soft cloth after 24 to 48 hours. However, if excessive wetting or mechanical force is used, premature tape separation may result. Patients may be instructed to gently trim curled edges of the closure tape with fine scissors to avoid premature loss of the tape.

Complications

Complications are uncommon with tape closure. The wound infection rate in clean wounds closed with tape compares favorably with rates for other standard closures.[1] However, some investigators believe that tape closure leads to inferior cosmetic results.[8] Premature tape separation occurs in approximately 3% of cases.[6] Other complications include (1) skin blistering, which occurs if the tape is not properly anchored with the cross strip or the tape is stretched too tightly across the wound, and (2) wound hematoma, which results if hemostasis is inadequate. Tape may loosen prematurely over shaved areas as hair grows back.

When tincture of benzoin is used, it should be applied carefully to the surrounding, uninjured skin. If spillage occurs into the wound, the wound is at higher risk for infection.[9] Benzoin vapors cause pain when applied near an open wound that has not been anesthetized. Benzoin can also injure the conjunctival and corneal membranes of the eye.

Summary

Modern tape products and techniques serve a valuable role in minor wound management of ED patients. Tape closure in selected wounds is as successful as suture closure. [1] [10] Closure tapes should be considered for superficial wounds in cosmetically unimportant areas and for wounds on relatively flat surfaces that are too wide for simple dressings but do not require sutures.

TISSUE ADHESIVE (TISSUE GLUE)

Tissue adhesive (also called tissue “glue”) provides a simple, rapid method of wound closure. Tissue adhesive has been approved for use in the United States since 1998. Two types of tissue adhesives are available: *N*-2-octylcyanoacrylate (Dermabond, Ethicon, Inc) and *N*-butyl-2-cyanoacrylate (Indermil, Tyco Healthcare Group LP). Dermabond and Indermil are packaged in sterile, single-use ampules. These bonding agents can be used on superficial wounds, even in hair-bearing areas. Tissue adhesives polymerizes on contact with water. These substances are biodegradable but remain in the wound until well after healing.[11]

Procedure

Tissue adhesive can be used to approximate wounds not requiring deep-layer closure. In preparation for closure, the wound should be anesthetized and cleaned and, when necessary, débrided. *Bleeding must be controlled*.

As the wound edges are held together with forceps, gauze pads, or fingers, a small, cylindrical plastic container is squeezed to expel droplets of tissue adhesive through a cotton applicator tip at the end of the container. The adhesive is applied in at least three to four thin layers along the length of the wound's surface and extending about 5 to 10 mm from each side of the wound (Fig. 35–4). Alternatively, one can place the adhesive in strips perpendicular to the laceration (analogous to placement of closure tapes). The purple color of the solution facilitates placement of the droplets. The wound edges should be supported, with edges held together, for at least 1 minute while the

adhesive dries. The low-viscosity tissue adhesives may seep into the wound or trickle off rounded surfaces during application. This tendency toward migration or “runoff” can be minimized by using high-viscosity adhesives,[12] positioning the wound horizontally, or slowly applying the adhesive. Runoff can be contained with wet gauze or by creating a barrier of petrolatum.

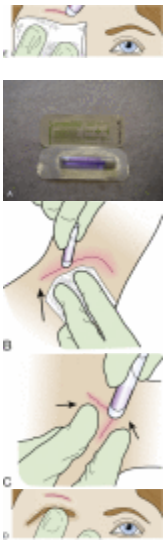

Figure 35–4 *A,* Tissue adhesive, 2-octylcyanoacrylate, comes in a variety of commercially available dispensers. *B,* To apply tissue adhesive (glue), the laceration must be dry. High-viscosity glue limits runoff. *C,* Bring the edges together, using a gauze pad or fingers, and apply glue in a few layers, with drying between applications. Do not get the glue in the eyes. *D,* Near the eye, keep the patient supine and *tilt the head* to avoid eye contamination and apply a layer of petroleum jelly as a barrier to the glue entering the eye. Do not apply the jelly to the area where the tissue adhesive must adhere. *E,* Alternatively, use a gauze barrier. If the adhesive enters the eye or lids, wipe it off with the gauze and flush with saline. Lids glued shut may be loosened with antibiotic ointment/petroleum jelly. If unsuccessful, tell the patient to shower normally and the eye will open in a few days as the glue sloughs off the lid. Note: *Glue that touches a latex glove, gauze, or plastic instrument (but not vinyl gloves or metal instruments) will glue them to the patient*.

Wound closures with tissue adhesive can be reinforced by pulling the wound edges into apposition with a few strips of porous surgical tape before the application of the adhesive. Tissue adhesive can be placed on top of surgical tape, but tape should not be placed on top of dried tissue adhesive. Once the adhesive has dried completely, the closure can be further protected with a nonocclusive bandage.

The primary advantage of tissue adhesive is the speed of closure. Wounds can be closed in as little as one sixth of the time required for repair with sutures. Application is rapid and painless. Use of tissue adhesive avoids suture marks adjacent to the wound and reduces the risk of needle stick injuries to health care personnel. Wounds closed with tissue adhesive have less tensile strength than sutured wounds in the first 4 days, [13] [14] but 1 week after closure, the tensile strength and overall degree of inflammation in wounds closed with tissue adhesive were equivalent to those closed with sutures. [11] [15] Cosmetic results are similar to those obtained with suture repair. [14] [16] [17] [18] [19] [20] [21] [22] Tissue adhesive serves as its own wound dressing and has an antimicrobial effect against gram-positive organisms. [23] [24] The material sloughs off in 5 to 10 days, thereby saving the patient from a clinician visit. Ointments or occlusive bandages should not be placed on wounds closed with tissue adhesive.

Complications

Percutaneous sutures provide a more secure immediate closure than tissue adhesive.[11] Although tissue adhesive is classified as nontoxic and does not cause a significant foreign body reaction, it should not be placed within the wound cavity. [14] [15] If hemostasis is inadequate or an excessive amount of adhesive is applied too quickly, the patient can experience a burning sensation or sustain a local burn from the heat of polymerization. After polymerizing, tissue adhesive can fracture with excessive or repetitive movement. Although gentle rinsing is permitted, if the adhesive is washed or soaked, it will peel off in a few days, before the wound is healed.[14]

If the clinician's gloved fingers, gauze, or plastic instruments contact the tissue adhesive during application, the glove may adhere to the patient's skin. Tissue adhesive can be removed with antibiotic ointment, petrolatum jelly, or more rapidly with acetone.[22] Indermil must be stored under refrigeration.

One risk involving the use of tissue adhesive is its ease of use—clinicians may fail to adequately clean wounds before closure with tissue adhesive.[25] Tissue adhesive should not be used to close infected wounds. If the wound edges cannot be held together without considerable tension, tissue adhesive should not be used.[22] Tissue adhesive should not be used near the eyes, over or near joints, on moist or mucosal surfaces, or on wounds under significant static or dynamic skin tension. See Figure 35–4 for information on managing eyelids that are accidentally glued shut.

SUTURES

In the United States, most traumatic wounds are closed by suturing.

Equipment

Instruments

In addition to the instruments used for débridement, a needle holder and suture scissors are required for suturing. The mechanical performance of disposable needle holders distributed by different surgical instrument companies varies considerably.[40] The size of the needle holder should match the size of the needle selected for suturing—that is, the needle holder should be large enough to hold the needle securely as it is passed through tissue, yet not so large that the needle is crushed or bent by the instrument.

Instruments used to débride a grossly contaminated wound should be discarded and replaced by fresh instruments for the closure. Instruments covered with coagulated blood can be cleansed with hydrogen peroxide, rinsed with sterile saline or water, and then used for suturing.

Suture Materials

A wide variety of suture materials are available. For most wounds that require closure of more than one layer of tissue, the clinician must choose sutures from two general categories: an absorbable suture for deeper, subcutaneous (SQ) layer and a nonabsorbable suture for surface (percutaneous) closure.

Sutures can be described in terms of four characteristics:

1. Composition (i.e., chemical and physical properties).
2. Handling characteristics and mechanical performance.
3. Absorption and reactivity.

4. Size and retention of tensile strength.

Composition

Sutures are made from natural fibers (cotton, silk), from sheep submucosa or beef serosa (plain gut, chromic gut), or from synthetic materials such as nylon (Dermalon, Ethilon, Nurulon, Surgilon), Dacron (Ethiflex, Mersilene), polyester (Ti-Cron), polyethylene (Ethibond), polypropylene (Prolene, Surgilene), polyglycolic acid (Dexon), and polyglactin (Vicryl, coated Vicryl). Stainless steel sutures are rarely, if ever, useful in wound closure in the ED setting because of handling difficulty and fragmentation. Some sutures are made of a single filament (monofilament); others consist of multiple fibers braided together (Table 35–1).[41]

TABLE 35–1 -- Examples of Suture Materials

Absorbable Sutures	Nonabsorbable Sutures
Monofilament	
Plain gut Chromic gut PDS (polydioxanone) Maxon (polyglyconate)	Dermalon (nylon) Ethilon (nylon) Prolene (polypropylene) Silk Steel Surgilene (polypropylene) Tevdek (Teflon-coated)
Multifilament	
Dexon (polyglycolic acid) Coated Vicryl (polyglactin)	Ethibond (polyethylene) Mersilene (braided polyester) Nurulon (nylon) Surgilon (nylon) TiCron (polyester)

Handling and Performance

Desirable handling characteristics in a suture include smooth passage through tissues, ease in knot tying, and stability of the knot once tied (Table 35–2). Smooth sutures pull through tissues easily, but knots slip more readily. Conversely, sutures with a high coefficient of friction have better knot-holding capacity but are difficult to slide through tissues. Smooth sutures will loosen after the first throw of a knot is made, and a second throw is needed to secure the first in place. However, the clinician may want to tighten a knot further after the first throw is made. This is difficult with rougher types of sutures.

TABLE 35–2 -- Characteristics of Suture Materials

Suture Material	Knot Security	Tensile Strength	Tissue Reactivity	Duration of Suture Integrity (days)	Tie Ability (Handling)
Absorbable					
Surgical gut	Poor	Fair	Greatest	5–7	Poor
Chromic gut	Fair	Fair	Greatest	10–14	Poor
Coated Vicryl	Good	Good	Minimal	30	Best
Dexon	Best	Good	Minimal	30	Best
PDS	Fair	Best	Least	45–60	Good
Maxon	Fair	Best	Least	45–60	Good
Nonabsorbable					
Ethilon	Good	Good	Minimal		Good
Prolene	Least	Best	Least		Fair
Silk	Best	Least	Greatest		Best

Modified with permission from Hollander J, Singer A: Laceration management. Ann Emerg Med 34:351, 1999.

Multifilament sutures have the best handling characteristics of all sutures, whereas steel sutures have the worst. In terms of performance and handling, significant improvements have been made in the newer absorbable sutures. Gut sutures have many shortcomings, including relatively low and variable strength, a tendency to fray when handled, and stiffness despite being packaged in a softening fluid. [42] [43] Multifilament synthetic absorbable sutures are soft and easy to tie and have few problems with knot slippage. Polyglactin 910 (coated Vicryl) sutures have an absorbable lubricant coating. The “frictional drag” of these coated sutures as they are pulled through tissues is less than that of uncoated multifilament materials, and the resetting of knots after the initial throw is much easier. This characteristic allows retightening of a ligature without knotting or breakage and with smooth, even adjustment of suture line tension in running subcuticular stitches.[44] Synthetic monofilament sutures have the troublesome property of “memory”—a tendency of the filament to spring back to its original shape, which causes the knot to slip and unravel. Some nonabsorbable monofilament sutures are coated with polytetrafluorethylene (Teflon) or silicone to reduce their friction. This coating improves the handling characteristics of these monofilaments but results in poorer knot security.[43]

Three square knots will secure a stitch made with silk or other braided, nonabsorbable materials, and four knots are sufficient for synthetic, absorbable, and nonabsorbable monofilament sutures.[45] Five knots are needed for the Teflon-coated synthetic Tevdek.[46] With the use of coated synthetic suture materials, attention to basic principles of knot tying is even more important. An excessive number of throws in a knot weakens the suture at the knot. If the clinician uses square knots (or a surgeon's knot on the initial throw, followed by square knots) that lie down flat and are tied securely, knots will rarely unravel.[47]

Absorption and Reactivity

Sutures that are rapidly degraded in tissues are termed *absorbable*; those that maintain their tensile strength for longer than 60 days are considered *nonabsorbable* (see Table 35–1). Plain gut may be digested by white blood cell lysozymes in 10 to 40 days; chromic gut will last 15 to 60 days. Remnants of both types of sutures, however, have been seen in wounds more than 2 years after their placement. [42] [45] [48] The Ethicon catgut is rapidly absorbed within 10 to 14 days but with less inflammation than that caused by chromic catgut.[49] Vicryl is absorbed from the wound site within 60 to 90 days [42] [45] and Dexon, within 120 to 210 days. [50] [51] When placed in the oral cavity, plain gut disappears after 3 to 5 days, chromic gut after 7 to 10 days, and polyglycolic acid after 16 to 20 days.[52] In contrast, SQ silk may not be completely absorbed for as long as 2 years.[45] The rate of absorption of synthetic absorbable sutures is independent of suture size.[50]

Sutures may lose strength and function before they are completely absorbed in tissues. Braided synthetic absorbable sutures lose nearly all of their strength after about 21 days. In contrast, monofilament absorbable sutures (modified polyglycolic acid [Maxon, Davis & Geck] and polydioxanone [PDS, Ethicon]) retain 60% of their strength after 28 days. [53] [54] Gut sutures treated with chromium salts (chromic gut) have a prolonged tensile strength; however, all gut sutures retain tensile strength erratically. [42] [45] Of the absorbable types of sutures, a wet and knotted polyglycolic acid suture is stronger than a plain or chromic gut suture subjected to the same conditions. [43] [55]

Polypropylene remains unchanged in tissue for longer than 2 years after implantation.[56] In comparison testing, sutures made of natural fibers such as silk, cotton, and gut are the weakest; sutures made of Dacron, nylon, polyethylene, and polypropylene are intermediate in tensile strength; and metallic sutures are the strongest.[43] The comparison of suture strength versus wound strength is a measure of the usefulness of a suture. Catgut is stronger than the soft tissue of a wound for no more than 7 days; chromic catgut, Dexon, and Vicryl are stronger for 10 to 21 days; and nylon, wire, and silk are stronger for 20 to 30 days.[57]

All sutures placed within tissue will damage host defenses and provoke inflammation. Even the least reactive suture impairs the ability of the wound to resist infection.[56] The magnitude of the reaction provoked by a suture is related to the quantity of suture material (diameter x total length) placed in the tissue and to the chemical composition of the suture. Among absorbable sutures, polyglycolic acid and polyglactin sutures are least reactive, followed by chromic gut. Nonabsorbable polypropylene is less reactive than nylon or Dacron. [43] [58] [59] Significant tissue reaction is associated with catgut, silk, and cotton sutures. Absorbable polyglycolic acid sutures are less reactive than those of nonabsorbable silk.[60] Highly reactive materials should be avoided in contaminated wounds.

The chemical composition of sutures is a factor in early infection. The infection rate in experimentally contaminated wounds closed with polyglycolic acid sutures is less than the rate when gut sutures are used.[56] However, other authors have compared plain gut and nonabsorbable nylon sutures for skin closures in children and found comparable cosmetic results and infection rates.[61] Lubricant coatings on sutures do not alter suture reactivity, absorption characteristics, breaking strength, or the risk of infection. [44] [56] Multifilament sutures provoke more inflammation and are more likely to produce infection than monofilament sutures if left in place for prolonged periods. [62] [63] Monofilament sutures elicit less tissue reaction than do multifilament sutures, and multifilament materials tend to wick up fluid by capillary action. Bacteria that adhere to and colonize sutures can envelop themselves in a glycocalix that protects them from host defenses,[64] or they can “hide” in the interstices of a multifilament suture and, as a result, be inaccessible to leukocytes.[62] PDS provides the advantages of a monofilament suture in an absorbable form, making it a good choice as a subcuticular stitch. Polypropylene sutures have a low coefficient of friction, and subcuticular stitches with this material are easy to pull out.[65]

Size and Strength

Size of suture material (thread diameter) is related to the tensile strength of the suture; threads of greater diameter are stronger. The strength of the suture is proportional to the square of the diameter of the thread. Therefore, a 4-0 suture of any type is larger and stronger than a 6-0 suture. The correct suture size for approximation of a layer of tissue depends on the tensile strength of that tissue. The tensile strength of the suture material should be only slightly greater than that of the tissue, because the magnitude of damage to local tissue defenses is proportional to the amount of suture material placed in the wound. [45] [66]

Synthetic absorbable sutures have made the older, natural suture materials unnecessary for most wound closures. Polyglycolic acid (Dexon) and polyglactin 910 (coated Vicryl) have improved handling characteristics, knot security, and tensile strength. Their absorption rates are predictable, and tissue reactivity is minimal. [67] [68] The distinct advantages of synthetic nonabsorbable sutures over silk sutures are their greater tensile strength, low coefficient of friction, and minimal tissue reactivity. [56] [67] They are extensible, elongating without breaking as the edges of the wound swell in the early postoperative period. [66] [67] In contrast with silk sutures, synthetics can be easily and painlessly removed once the wound has healed. The monofilament synthetic suture Novofil has elasticity that allows a stitch to enlarge with wound edema and to return to its original length once the edema subsides. Stiffer materials lacerate the encircled tissue as the wound swells. [69]

The suture materials most useful to emergency clinicians for wound closure are Dexon or coated Vicryl for SQ layers and synthetic nonabsorbable sutures (e.g., nylon or polypropylene) for skin closure. Fascia can be sutured with either absorbable or nonabsorbable materials. In most situations, 3-0 or 4-0 sutures are used in the repair of fascia, 4-0 or 5-0 absorbable sutures in SQ closure, and 4-0 or 5-0 nonabsorbable sutures in skin closure. Lips, eyelids, and the skin layer of facial wounds are repaired with 6-0 sutures, whereas 3-0 or 4-0 sutures are used when the skin edges are subjected to considerable dynamic stresses (e.g., wounds overlying joint surfaces) or static stresses (e.g., scalp).

Needles

The eyeless, or “swaged,” needle is used for wound closure in most emergency centers (Fig. 35–12). Selection of the appropriate needle size and curvature is based on the dimensions of the wound and the characteristics of the tissues to be sutured. The needle should be large enough to pass through tissue to the desired depth and then to exit the tissue or the skin surface far enough that the needle holder can be repositioned on the distal end of the needle at a safe distance from the needle point (Fig. 35–13). Although it is tempting to use the fingers to grasp the needle tip to pull the needle through the skin, this practice risks a needle stick. The clinician should either reposition the needle holder or use forceps to disengage the needle from the laceration.

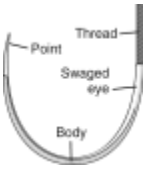

Figure 35–12 The eyeless, or “swaged,” needle. *(From Suture Use Manual: Use and Handling of Sutures and Needles. Somerville, NJ, Ethicon, Inc, 1977, p 29. Reproduced by permission.)*

Figure 35–13 The needle should be large enough to pass through tissue and should exit far enough to enable the needle holder to be repositioned on the end of the needle at a safe distance from the point.

In wound repair, needles must penetrate tough, fibrous tissues—skin, SQ tissue, and fascia—yet should slice through these tissues with minimal resistance or trauma and without bending. The type of needle best suited for closure of SQ tissue is a conventional cutting needle in a three eighths or one half circle (Fig. 35–14). Double-curvature needles (coated Vicryl with PS-4-C cutting needles, Ethicon) may be easier to maneuver in narrow, deep wounds. For surface closure, a conventional cutting-edge needle permits more precise needle placement and requires less penetration force (Fig. 35–15). [70] [71]

Figure 35–14 One half and three eighths circle needles, used for most traumatic wound closures.

Figure 35–15 Types of needles. *A,* The conventional cutting needle has two opposing cutting edges, with a third edge on the inside curvature of the needle. The conventional cutting needle changes in cross-section from a triangular cutting tip to a flattened body. *B,* The reverse cutting needle is used to cut through tough, difficult-to-penetrate tissues such as fascia and skin. It has two opposing cutting edges, with the third cutting edge on the outer curvature of the needle. The reverse cutting needle is made with the triangular shape extending from the point to the swage area, with only the edges near the tip being sharpened. *(From Suture Use Manual: Use and Handling of Sutures and Needles. Somerville, NJ, Ethicon, Inc, 1977, p 31. Reproduced by permission.)*

Suturing Techniques

Skin Preparation

Before suturing, the clinician should ensure adequate exposure and illumination of the wound, with the patient placed at an appropriate height. The clinician should assume a comfortable standing or sitting position at one end of the long axis of the wound.

The skin surrounding it is prepared with a povidone-iodine solution and covered with sterile drapes. Some surgeons do not drape the face but prefer to leave facial structures and landmarks adjacent to the wound uncovered and within view. A clear plastic drape (Steri-Drape, 3M Corporation) can be used to provide a sterile field and a limited view of the area surrounding the wound. If no drapes are used on the face, the skin surrounding the wound should be widely cleansed and prepared. Wrapping the hair in a sheet or placing the patient's hair in an oversized scrub hat prevents stray hair from falling into the operating field

Closure Principles

There is a tendency to overuse sutures for minor lacerations that will heal nicely with no intervention. Therefore, before suturing, one must assess the need for the procedure (Fig. 35–16).

Figure 35–16 There is a tendency to overuse sutures. *A,* This child sustained a superficial forehead laceration just through the epidermis. The swelling accentuated the defect. Treatment was simply keeping the laceration clean. *B,* Four months after the injury, an excellent result was obtained. As the laceration was healing, it became red and more noticeable, *as do all scars*, but eventually faded.

Three principles apply to the suturing of lacerations in any location: (1) minimize trauma to tissues, (2) relieve tension exerted on the wound edges by undermining and layered wound closure, and (3) accurately realign landmarks and skin edges by layered closure and precise suture placement.

Minimizing Tissue Trauma

The importance of careful handling of tissue has been emphasized since the early days of surgery. Skin and SQ tissue that has been stretched, twisted, or crushed by an instrument or strangled by a suture that is tied too tightly may undergo necrosis, and increased scarring and infection may result. When the edges of a wound must be manipulated, the SQ tissues should be lifted gently with a toothed forceps or skin hook, avoiding the skin surface.

When choosing suture sizes, the clinician should select the smallest size that will hold the tissues in place. Skin stitches should incorporate no more tissue than is needed to coapt the wound edges with little or no tension. Knots should be tied securely enough to approximate the wound edges but without blanching or indenting the skin surface.[72]

Relieving Tension

Many forces can produce tension on the suture line of a reapproximated wound. Static skin forces that stretch the skin over bones cause the edges of a new wound to gape, and they also continuously pull on the edges of the wound once it has been closed. Traumatic loss of tissue or wide excision of a wound may have the same effect. The best cosmetic result occurs when the long axis of a wound happens to be parallel to the direction of maximal skin tension; this alignment brings the edges of the wound together.[69]

Muscles pulling at right angles to the axis of the wound impose dynamic stresses. Swelling after an injury creates additional tension within the circle of each suture.[72] Skin suture marks result not only from tying sutures too tightly but also from failing to eliminate underlying forces distorting the wound. Tension can be reduced during wound closure in two ways: undermining of the wound edges and layered closure.

Undermining

The force required to reapproximate the wound edges correlates with the subsequent width of the scar.[73] Wounds subject to significant static tension require the undermining of at least one tissue plane on both sides of the wound to achieve a tension-free closure. To undermine a wound, the clinician frees a flap of tissue from its base at a distance from the wound edge approximately equal to the width of the gap that the laceration presents at its widest point (Fig. 35–17).

Figure 35–17 The technique of undermining is underused and can markedly improve cosmetic results by relieving wound tension. The scalpel is used to find an appropriate site; a natural plane often exists at the epidermis-dermis junction.

The depth of the incision can be modified, depending on the orientation of the laceration to skin tension lines and the laxity of skin in the area. A No. 15 scalpel blade held parallel to the skin surface is used to incise the adipose layer or the dermal layer of the wound. The clinician also can accomplish this technique by spreading scissors in the appropriate tissue plane. Undermining allows the skin edges to be lifted and brought together with gentle traction.[74] Potential complications of this procedure include injury to cutaneous nerves and creation of a hematoma under the flap.[57]

Because undermining may harm the underlying blood supply, this technique should be reserved for relatively uncontaminated wounds when no other methods adequately relieve wound tension.[70]

Layered Closure

The structure of skin and soft tissue varies with the location on the body (Fig. 35–18). Most wounds handled in an ED require approximation of no more than three layers: fascia (and associated muscle), SQ tissue, and skin surface (papillary layer of dermis and epidermis).[75] The presence of "dead space" (or unapposed edges) within a wound may fill with blood or exudate and enhance the development of infection. Closure of individual layers obliterates this dead space.

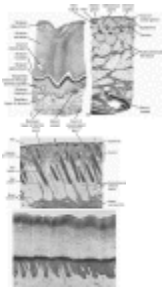

Figure 35–18 Variation in the structure of skin. *A,* Section of the skin of the scalp, x15. *B,* Skin of the human fingertip, illustrating a very thick stratum corneum. Hematoxylin and eosin, x65. *C,* Section of human sole perpendicular to the free surface, x100. *D,* Section through human thigh perpendicular to the surface of the skin. Blood vessels are injected and appear black. Low magnification. *(A, Courtesy of H Mizoguchi; C and D, after AA Maximow. From Bloom W, Fawcett DW: A Textbook of Histology, 10th ed. Philadelphia, WB Saunders, 1975. Reproduced by permission.)*

Separate approximation of muscle and SQ layers hastens the healing and return of function to the muscle. However, the fascia, not muscle, should be sutured. Muscle tissue itself is too friable to hold a suture. Layered closure is particularly important in the management of facial wounds; this technique prevents scarring of muscle to the SQ tissue and consequent deformation of the surface of the wound with contraction of the muscle. If a deep, gaping wound is closed without approximation of underlying SQ tissue, a disfiguring depression may develop at the site of the wound. Finally, layered closure provides support to the wound and considerably reduces tension at the skin surface.

Several exceptions exist to the general rule of multilayered closure. The adipose layer of soft tissue should not be closed separately. A "fat stitch" is not necessary, because little support is provided by closure of the adipose layer, and additional suture material may increase the possibility of infection.[2] [76] Scalp wounds are generally closed in a single layer. For lacerations penetrating the dermis in fingers, hands, toes, and feet and in the sebaceous skin of the nasal tip, the amount of SQ tissue is too small to warrant layered closure; in fact, SQ stitches may leave tender nodules in these sensitive locations. Layered closure is not recommended in wounds without tension, those with poor vascularity, and those with a moderate or high risk for infection. With single-layer closure, the surface stitch should be placed more deeply.[57]

Suture Placement

SQ Layer Closure

Once fascial structures have been reapproximated, the SQ layer is sutured. Although histologically the fatty and fibrous SQ tissue (hypodermis) is an extension of (and is continuous with) the reticular layer of the dermis,[77] suturing of these layers is traditionally referred to as a *SQ closure*. One approach is to close the length of this layer in segments, placing the first stitch in the middle of the

wound and bisecting each subsequent segment until the closure of the layer has been completed.[41] This technique is useful in the closure of wounds that are long or sinuous, and it is particularly effective in wounds with one elliptical and one linear side. The needle is grasped by the needle holder close to the suture end. The clinician can suture more rapidly if the fingers are placed on the midshaft of the needle holder rather than in the rings of the instrument (Fig. 35–19).

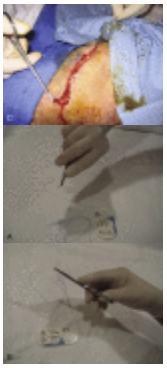

Figure 35–19 *A,* The thenar grip technique of handling the needle holder. The index finger is placed on the side of the needle holder, where it guides the placement of the needle. Neither the index nor the middle finger is placed in the ringlet hole. Note how the wrist is initially pronated, then supinated as the suture is placed. *B,* An alternate method, the thumb-ring finger grip. *C,* Note how a subcutaneous suture almost closes the wound, so there is minimal tension on the skin edges, while obliterating any subcutaneous space. Tie and bury the knot by pulling the *sutures in the long axis of the wound*. *(C, From Thomsen T, Setnik G [eds]: Procedures Consult—Emergency Medicine Module.*

The suture enters the SQ layer at the bottom of the wound (Fig. 35–20*A*) or, if the wound has been undermined, at the base of the flap (see Fig. 35–20*B*), and exits in the dermis. Once the suture has been placed on one side of the wound, it can be pulled across the wound to the opposite side (or the wound edges pushed together) to determine the matching point on the opposite side. The needle is then advanced into this point. The needle should enter the dermis at the same depth as it exited from the opposite side, pass through the tissue, and exit at the bottom of the wound (or the base of the flap). The edges of the wound can be closely apposed by pulling the two tails of the suture in the same direction along the axis of the wound (Fig. 35–21). Some clinicians place their SQ suture obliquely rather than vertically to facilitate knot tying. When the knot in this SQ stitch is tied, it will remain inverted, or “buried,” at the bottom of the wound. Burying the knot of the SQ stitch avoids a painful, palpable nodule beneath the epidermis and keeps the bulk of this foreign material away from the skin surface. Most emergency clinicians construct knots using the instrument tie technique. Hand and instrument knot-tying techniques are described and illustrated in wound care texts.[78] [79]

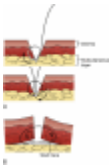

Figure 35–20 *A* and *B,* Inverted subcutaneous stitches.

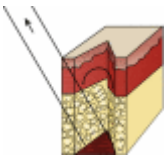

Figure 35–21 The two tails of the subcutaneous suture are pulled in the same direction, tightly apposing the edges of the wound.

Once the knot has been secured, the tails of the suture should be pulled taut for cutting. The scissors are held with the index finger on the junction of the two blades. The blade of the scissors is slid down the tail of the suture until the knot is reached. With the cutting edge of the blade tilted away from the knot, the tails are cut. This technique prevents the scissors from cutting the knot itself and leaves a tail of 3 mm, which protects the knot from unraveling.[80] The entire SQ layer is sutured in this manner.

After the SQ layer has been closed, the distance between the skin edges determines the approximate width of the scar in its final form. If this width is acceptable, surface sutures can be inserted.[81] Despite undermining and placement of a sufficient number of SQ sutures, on occasion a large gap between the wound edges may persist. In such cases, a horizontal dermal stitch may be used to bridge this gap (see Fig. 35–40).

Surface Closure

The epidermis and the superficial layer of dermis are sutured in a single layer with nonabsorbable synthetic sutures. The choice of suture size, the number of sutures used, and the depth of suture placement depend on the amount of skin tension remaining after SQ closure.

If the edges of the wound are apposed after closure of deeper layers, small 5-0 or 6-0 sutures can be used simply to match the epithelium of each side. Wounds with greater tension and separation should have skin stitches placed closer to each other and closer to the wound edge; layered closure is important in such wounds. If the wound edges remain retracted or if SQ stitches were not used, a larger-size suture placed deeply may be required.

The number of sutures used in closing any wound will vary with the wound location, the amount of tension on the wound, and with the degree of accuracy required by the clinician and patient. For example, sutures on the face would probably be placed between 1 and 3 mm apart.[62] Unless the wound edges are uneven, sutures should be placed in a mirror-image fashion such that the depth and width are the same on both sides of the wound.[45] In general, the distance between each suture should be approximately equal to the distance from the exit of the stitch to the wound edge. [41] [78]

Skin closure may be accomplished with sutures placed in segments (Fig. 35–22) using the appropriate number of sutures (Fig. 35–23). When suturing the skin, right-handed operators should pass the needle from the right side of the wound to the left. The needle should be driven through tissue by flexing the wrist and supinating the forearm; *the course taken by the needle should result in a curve identical to the curvature of the needle itself* (Fig. 35–24). *The angle of exit for the needle should be the same as its angle of entrance so that an identical volume of tissue is contained within the stitch on each side of the wound* (Fig. 35–25).

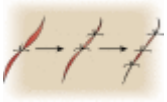

Figure 35–22 Closure of the surface of the wound in segments rather than from one end. Place the first suture in the center of the wound for a straight suture line.

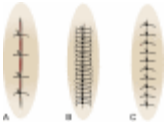

Figure 35–23 *A,* Too few stitches used. Note gaping between sutures. *B,* Too many stitches used. *C,* Correct number of stitches used for a wound under an average amount of tension.

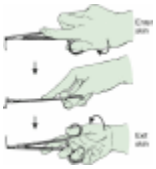

Figure 35–24 Motion of the needle holder mimics the curve of the needle. Rotate the wrist (pronate) so the needle enters the skin perpendicularly, not at an angle, as the wrist supinates. This helps evert the wound edge. *(From Anderson CB: Basic surgical techniques. In Klippel AP, Anderson CB [eds]: Manual of Outpatient and Emergency Surgical Techniques. Boston, Little, Brown, 1979. Reproduced by permission.)*

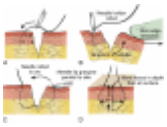

Figure 35–25 The simple suture. *A,* Hold the needle pointing down by excessively pronating the wrist so that the needle tip initially moves farther from the laceration as the needle penetrates deeper into the skin. (See also Fig. 35–19 .) Drive the needle tip downward and away from the cut edge, into the subcutaneous layer. *B,* Advance the needle into the laceration. The needle tip is directed toward the opposite side at the same level by rolling the needle holder. The arc of the needle pathway is controlled by retracting the skin edge. This method incorporates more tissue within the stitch in the deeper layers of the wound than at the surface. As an alternative, if a small needle is used in thick skin or the distance across the wound is great, the needle can be removed from the first side, remounted on the needle holder, and advanced to the opposite side. *C,* Advance the needle upward toward the surface so that it exits at the same distance from the wound edge as on the contralateral side of the wound. Grasp the needle behind the tip and roll it out in the arc of the needle. *D,* The final position, with more tissue in the depth than in the surface. The distance from each suture exit to the laceration is half the depth of the dermis. *(A–D, Redrawn from Kaplan EN, Hentz VR: Emergency Management of Skin and Soft Tissue Wounds: An Illustrated Guide. Boston, Little, Brown, 1984, p 86. Reproduced by permission.)*

Once the needle exits the skin on the opposite side of the wound, it is regrasped by the needle holder and advanced through the tissue; care should be taken to avoid crushing the point of the needle with the instrument. Forceps are designed for handling tissue and thus should not be used to grasp the needle. The forceps can stabilize the needle by holding the needle within the tissue through which the needle has just passed. An assistant can keep excess thread clear of the area being sutured or the excess can be looped around the clinician's fingers. If the point of the needle becomes dulled before all of the attached thread has been used, the suture should be discarded.

Complications

Sutures act as foreign bodies in a wound, and any stitch may damage a blood vessel or strangulate tissue. Therefore, the clinician should use the smallest size and the least number of sutures that will adequately close the wound.[56] However, if spaced too widely, surface stitches will leave a “crosshatch” pattern of marks.

Encompassing too much tissue with a small needle is a common error. Forcefully pushing or twisting the needle in an effort to bring the point out of the tissue may bend or break the body of the needle. Using a needle of improper size will defeat the best suturing technique.

If sutures are tied too tightly around wound edges or if individual stitches are under excessive tension, blood supply to the wound may be impeded, increasing the chance of infection, and suture marks may form even after 24 hours. [45] [82]

If the techniques described are applied to most wounds, the edges will be matched precisely in all three dimensions, using the least number of sutures required to appose edges and relieve tension but avoid excessive scarring.

Eversion Techniques

If the edges of a wound invert, or if one edge rolls under the opposite side, a poorly formed, deep, noticeable scar will result. Excessive eversion that exposes the dermis of both sides also will result in a larger scar than if the skin edges are perfectly apposed, but inversion produces a more visible scar than does eversion. Because most scars undergo some flattening with contraction, optimal results are achieved when the epidermis is slightly everted without excessive suture tension (Fig. 35–26). Wounds over mobile surfaces, such as the extensor surfaces of joints, should be everted. In time, the scar will be flattened by the dynamic forces acting in the area.

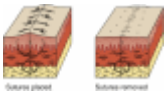

Figure 35–26 Skin edges that are slightly *everted* will gradually flatten to produce a level wound surface when the sutures are removed. An inverted wound catches the light in a shadow and is more visible. In addition, eversion allows subcutaneous tissue to heal. *(From Grabb WC: Basic technique of plastic surgery. In Grabb WC, Smith JW [eds]: Plastic Surgery: A Concise Guide to Clinical Practice. Boston, Little, Brown, 1979. Reproduced by permission.)*

Numerous techniques can be used to avoid inversion of the edges of the wound. If the clinician angles the needle obliquely away from the laceration, a surface stitch can be placed so that it is *deeper than it is* wide[74] and the stitch encircles more tissue in the SQ layer than at the surface. If this “bottle-shaped stitch” is intended to produce some eversion of the wound edges, the stitch must include a sufficient amount of SQ tissue (see Fig. 35–25*D*).

Eversion can be accomplished by lifting and turning the edge of the wound outward with a skin hook or fine-tooth forceps before insertion of the needle on each side (Fig. 35–27). Eversion can also be obtained simply by pressing on the skin adjacent to the wound with a closed forceps (or thumb and a finger as long as a needle stick is avoided) (Fig. 35–28).

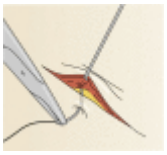

Figure 35–27 The use of a forceps or skin hook to evert the wound edge. This technique allows the operator to see the needle path, ensuring that the proper depth has been reached, and promotes eversion of the skin edges.

Figure 35–28 Eversion of the wound edge by thumb and finger pressure *kept away from the needle to avoid a needle stick*. *(From Converse JM: Introduction to plastic surgery. In Converse JM [ed]: Reconstructive Plastic Surgery: Principles and Procedures in Correction, Reconstruction, and Transplantation, vol 1, 2nd ed. Philadelphia, WB Saunders, 1977. Reproduced by permission.)*

Vertical mattress sutures are particularly effective in everting the wound edges, and they can be used exclusively or alternated with simple interrupted sutures (Fig. 35–29).[83] In wounds that have been undermined, an SQ stitch placed at the base of the flap on each side can in itself evert the wound (Fig. 35–30).

Figure 35–29 The vertical mattress suture is the *best technique for producing skin edge eversion*. *A,* The usual type of mattress suture for approximating and everting wound edges. *B,* "Tacking" type of vertical mattress suture, extending into deep fascia to obliterate dead space under wound. Note that only a small bite of skin is included on the inner suture. *(Modified from Converse JM: Introduction to plastic surgery. In Converse JM [ed]: Reconstructive Plastic Surgery: Principles and Procedures in Correction, Reconstruction, and Transplantation, vol 1, 2nd ed. Philadelphia, WB Saunders, 1977. Reproduced by permission.)*

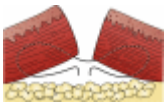

Figure 35–30 Deep dermis suturing technique. The suture enters the base of the flap, is brought up into the dermis, and exits just proximal to the wound edge along the base of the flap to be tied and cut. *(From Stuzin J, Engrav LH, Buehler PK: Emergency treatment of facial lacerations. Postgrad Med 71:81, 1982. Reproduced by permission.)*

Interrupted Stitch

The simple interrupted stitch is the most frequently used technique in the closure of skin. It consists of separate loops of suture individually tied. Although the tying and cutting of each stitch are time-consuming, the advantage of this method is that if one stitch in the closure fails, the remaining stitches continue to hold the wound together (Fig. 35–31).

Figure 35–31 Simple interrupted stitch. Additional throws in a partially tied knot are not shown. *(From Grabb WC: Basic techniques of plastic surgery. In Grabb WC, Smith JW [eds]: Plastic Surgery: A Concise Guide to Clinical Practice. Boston, Little, Brown, 1979. Reproduced by permission.)*

Continuous Stitch

A continuous stitch is an effective method for closing relatively clean, low-risk wounds that are under little or no tension and are on flat, immobile skin surfaces. In a continuous, or "running," stitch, the loops are the exposed portions of a helical coil tied at each end of the wound. A continuous suture line can be placed more rapidly than a series of interrupted stitches. The continuous stitch has the additional advantages of strength (with tension being evenly distributed along its entire length), fewer knots (which are the weak points of stitches), and more effective hemostasis. This stitch will accommodate mild wound swelling. The continuous technique is useful as an epithelial or "surface" stitch in cosmetic closures; however, if the underlying SQ layer is not stabilized in a separate closure, the continuous surface stitch tends to invert the wound edges.

The continuous suture technique has some disadvantages. This technique cannot be used to close wounds overlying joints. If a loop breaks at one point, the entire stitch may unravel. Likewise, if infection develops and the incision must be opened at one point, cutting a single loop may allow the entire wound to fall open. The simple continuous stitch has a tendency to produce suture marks if used in large wound closures and if left in place for more than 5 days.[72] However, if all tension on the wound can be removed by SQ sutures, stitch marks are seldom a problem.

Among the variations of the continuous technique, the simple continuous stitch is the most useful to emergency clinicians (Fig. 35–32). An interrupted stitch is placed at one end of the wound, and only the free tail of the suture is cut. As suturing proceeds, the stitch encircles tissue in a spiral pattern. After each passage of the needle, the loop is tightened slightly, and the thread is held taut in the clinician's nondominant hand. The needle should travel perpendicularly across the wound on each pass. The last loop is placed just beyond the end of the wound, and the suture is tied, with the last loop used as a “tail” in the process of tying the knot (Fig. 35–33). A locking loop may be used in continuous suturing to prevent slippage of loops as the suturing proceeds (Fig. 35–34). The interlocking technique allows the use of the continuous stitch along an irregular laceration.[74]

Figure 35–32 Simple continuous stitch. *(From Grabb WC: Basic techniques of plastic surgery. In Grabb WC, Smith JW [eds]: Plastic Surgery: A Concise Guide to Clinical Practice. Boston, Little, Brown, 1979. Reproduced by permission.)*

Figure 35–33 Completing the simple continuous stitch. A series of square knots is tied, with the loop as one of the ties.

Figure 35–34 Continuous interlocking stitch. *(Modified from Suture Use Manual: Use and Handling of Sutures and Needles. Somerville, NJ, Ethicon, Inc, 1977. Reproduced by permission.)*

Continuous Subcuticular Stitch

Nonabsorbable sutures used in surface closure outlast their usefulness and must be removed. On occasion, wounds require an extended period of support, longer than that provided by surface stitches. Some patients with wounds that require skin closure are unlikely or unwilling to return for suture removal. Some sutured wounds are covered by plaster casts. On occasion, the patient (child or adult) is likely to be as frightened and uncooperative for suture removal as for suture placement. Surface sutures are more likely to produce stitch marks in children because the wounds are under greater tension than those in adults. The continuous subcuticular (or “dermal”) suture technique is ideal for these situations; the wound can be closed with an absorbable subcuticular stitch, obviating the need for later suture removal. In patients prone to keloid formation, the subcuticular technique can be used in lieu of surface stitches, which avoids disfiguring stitch marks. Buried, absorbable

subcuticular stitches do not appear to provoke more inflammation than percutaneous running stitches with monofilament nylon.[71] Because stitch marks are not a problem, a nonabsorbable subcuticular suture can be left in place for a longer period than a surface suture.[83]

Although this technique is commonly used in cosmetic closures, closure of the subcuticular layer alone may not alter the scar width.[84] This technique does not allow for perfect approximation of the vertical heights of the two edges of a wound,[85] and in cosmetic closures, it is often followed by a surface stitch. The subcuticular stitch requires a 4-0 or 5-0 suture made of either absorbable material or nonabsorbable synthetic monofilament. An absorbable suture can be "buried" within the wound, whereas a nonabsorbable suture is used for a "pull-out" stitch. The absorbable synthetic monofilament suture PDS (Ethicon) is designed for subcuticular closure. It passes through tissues as easily as nonabsorbable monofilament sutures and is absorbed if left in the wound.

Before the subcuticular stitch is begun, the SQ layer should be approximated with interrupted sutures to minimize tension on the wound. The pull-out subcuticular stitch is started at the skin surface approximately 1 to 2 cm away from one end of the wound. The needle enters and exits the dermis at the apices of the wound (Fig. 35–35). Bites through tissue are taken in a horizontal direction, with the needle penetrating the dermis 1 to 2 mm from the skin surface. These intradermal bites should be small, of equal size, and at the same level on each side of the wound. [68] [83] Each successive bite should be placed 1 to 2 mm behind the exit point on the opposite side of the wound so that when the wound is closed, the entrance and exit points on either side are not directly apposed (Fig. 35–36). Small bites should be taken to avoid puckering of the skin surface, and the stitch should not be accidentally interlocked. Some clinicians prefer to place a fine (6-0) running skin suture on the surface, in addition to the subcuticular suture, for meticulous skin approximation. The skin suture is removed in 3 to 4 days to avoid suture marks.

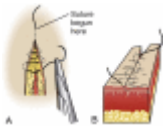

Figure 35–35 Pull-out subcuticular stitch. For deep wounds, first place interrupted sutures to relieve tension on skin edge. The suture is introduced into the skin in line with the incision, approximately 1–2 cm away. *(From Grimes DW, Garner RW: "Reliefs" in intracuticular sutures. Surg Rounds 1:46, 1978. Reproduced by permission and from Grabb WC: Basic techniques of plastic surgery. In Grabb WC, Smith JW [eds]: Plastic Surgery: A Concise Guide to Clinical Practice. Boston, Little, Brown, 1979. Reproduced by permission.)*

Figure 35–36 In constructing the relief to facilitate suture removal, the suture is crossed to the opposite side, going into the subcuticular area beneath the skin for approximately 2 cm before exiting (*A*). The suture is then carried over the epidermis for approximately 2 cm (*B*) and then back under the dermis again (*C*). Reentry is made into the wound area (*D*) at approximately the same location where the next "bite" would have been placed had the relief not been used. *(From Grimes DW, Garner RW: "Reliefs" in intracuticular sutures. Surg Rounds 1:47, 1978. Reproduced by permission.)*

If the subcuticular stitch is used on lengthy lacerations, it is difficult to remove the suture. The placement of "reliefs," consisting of periodic loops through the skin every 4 to 5 cm along the length of the stitch, facilitates later removal (see Fig. 35–36). The suture is crossed to the opposite side, and the needle is passed from SQ tissue to the skin surface. The suture is carried over the surface for approximately 2 cm before reentering the skin and SQ tissue. The subcuticular stitch is then

continued at approximately the point at which the next bite would have been placed had the relief not been used.

At the completion of the stitch, the needle is placed through the apex to exit the skin 1 to 2 cm away from the end of the wound. The stitch should be tightened by pulling each end taut. If reliefs have been used, pulling on the reliefs will take up any slack in the stitch. The clinician can secure the two ends of the stitch by taping them to the skin surface with wound closure tape, by placing a cluster of knots on each tail close to the skin surface, or by tying the two ends of the suture to each other over a dressing. Laxity of the subcuticular stitch will occur as tissue swelling subsides 48 hours after wound closure. The stitch can be tightened at this time.

Subcuticular closure can be accomplished by using absorbable sutures that do not penetrate the skin. The closure is begun with a dermal or SQ suture placed at one end of the wound and secured with a knot. After placement of the continuous subcuticular stitch from apex to apex, the suture is pulled taut, and a knot is tied using a tail and a loop of suture (Fig. 35–37). The final knot can be buried by inserting the needle into deeper tissue; the needle exits several millimeters from the wound edge. By pulling on the needle end, the knot disappears into the wound.[67] The advantage of this technique is that there are no suture marks in the skin.

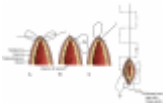

Figure 35–37 Subcuticular closure without epidermal penetration. *A,* The initial knot is secured in the dermal or subcutaneous tissue. *B,* The short strand is cut, and the needle is inserted into the dermis at the apex of the wound. *C,* The needle in the dermis, close to the corner of the wound and exiting the wound at the same horizontal level. *D,* After the subcuticular stitch has been completed, a knot is tied with the tail and the loop of the suture. *(A–D, Modified from Stillman RM: Wound closure: Choosing optimal materials and methods. ER Rep 2:43, 1981.)*

Nonabsorbable subcuticular sutures can be left in place for 2 to 3 weeks, thus providing a longer period of support than surface sutures, without the problem of stitch marks.[72] If skin sutures are used in conjunction with the subcuticular stitch, they are removed in 3 to 4 days. A subcuticular closure in itself is stronger than a tape closure. If the subcuticular technique is used exclusively to approximate the skin surface, skin tape can be applied to correct surface unevenness and to provide a more accurate apposition of the epidermis.

The primary disadvantage of the subcuticular stitch is that it is time-consuming, especially when supporting surface stitches are used. Another, faster method that avoids penetrating the skin is the interrupted subcuticular stitch (Fig. 35–38).[83] Wounds with strong static skin tension may benefit from a few interrupted dermal stitches placed horizontally to the skin surface instead of a continuous subcuticular stitch.

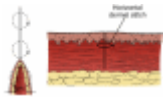

Figure 35–38 Interrupted subcuticular stitch (also called a horizontal dermal stitch). Absorbable sutures are used. (A vertical suture also closes the deep tissue.)

Mattress Stitch

The various types of mattress stitches are all interrupted stitches. The *vertical mattress stitch* is an effective method of everting skin edges (Fig. 35–39 ; see also Fig. 35–29). The vertical mattress

stitch may be used to take a deep bite of skin, eliminating the need for a layered closure in areas where excessive tension does not result. If the superficial loop is placed first, the tails can be pulled upward while the deep loop is placed, ensuring wound eversion in less time than with the traditional technique.[86]

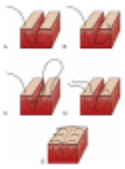

Figure 35–39 Steps in the vertical mattress stitch. The key to close apposition and exact alignment of edges is to place the inner sutures very close to the suture line (wound edge).

The *horizontal mattress stitch* is an SQ stitch that is oriented 90° to the interrupted SQ stitch described previously. The horizontal mattress stitch apposes skin edges closely while providing some degree of eversion (Fig. 35–40).[72] The horizontal mattress suture may be ideal for areas where eversion is desirable but there is little SQ tissue.

Figure 35–40 *A,* Horizontal mattress stitch. *B,* The dorsum of the hand, foot, or finger is an ideal place for a horizontal mattress suture to evert the wound edges. The relatively thin skin in these areas precludes the use of vertical mattress sutures. *(A, From Grabb WC: Basic techniques of plastic surgery. In WC, Smith JW [eds]: Plastic Surgery: A Concise Guide to Clinical Practice. Boston, Little, Brown, 1979. Reproduced by permission.)*

The *half-buried horizontal mattress stitch* is particularly useful in suturing the easily damaged apex of a V-shaped flap (Fig. 35–41). In the execution of the “corner stitch,” the suture needle penetrates the skin at a point beyond the apex of the wound and exits through the dermis. The corner of the flap is elevated, and the suture is passed through the dermis of the flap. The needle is then placed in the dermis of the base of the wound and returned to the surface of the skin. All dermal bites should be placed at the same level. The suture is tied with sufficient tension to pull the flap snugly into the corner without blanching the flap.[72] [87] If the tip of a large flap with questionable viability may be further jeopardized by postoperative swelling, a cotton stent can be placed underneath the knot of the corner stitch. The cotton absorbs the tension produced by swelling.

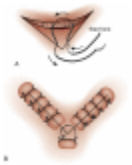

Figure 35–41 *A* and *B,* Corner stitch: Approximation of a flap with a half-buried horizontal mattress stitch, followed by interrupted sutures for the rest of the wound.

The only disadvantage of the horizontal and vertical mattress stitches is that they cause more ischemia and necrosis inside their loops than either simple or continuous stitches.[88]

Figure-of-Eight Stitch

The figure-of-eight stitch is useful in wounds with friable tissue, on the eyelids where the skin is too thin for buried sutures, or in areas in which buried sutures are undesirable (Fig. 35–42).[89] This stitch reduces the amount of tension placed on the tissue by the suture, allowing the stitch to hold in place when a simple stitch would tear through the tissue. The disadvantage of this technique is that more suture material is left in the wound. A vertical variation of the figure-of-eight stitch is sometimes used to approximate close, parallel lacerations (Figs. 35–43 and 35–44).[90] Another technique involves a vertical mattress stitch.

Figure 35–42 Figure-of-eight stitch, two methods. *(Modified from Dushoff IM: About face. Emerg Med 6:11:1974. Reproduced by permission.)*

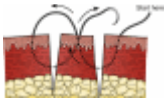

Figure 35–43 Vertical figure-of-eight suture technique. This can be used to close parallel lacerations. *(From Mitchell GC: Repair of parallel lacerations [letter]. Ann Emerg Med 16:924, 1987.)*

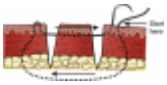

Figure 35–44 Technique for closure of parallel lacerations in which the central tissue island has an intact base. *(Redrawn from Samo DG: A technique for parallel lacerations. Ann Emerg Med 17:297, 1988.)*

Correction of Dog-Ears

When wound edges are not precisely aligned horizontally, there will be excess tissue on one or both ends. This small flap of excess skin that bunches up at the end of a sutured wound is commonly called a *dog-ear*. This effect also occurs when one side of the wound is more elliptical than the opposite side, or when an excision of a wound is not sufficiently elliptical because it is either too straight or too nearly circular. [41] [83]

If a dog-ear is present, it can be eliminated on one side of the wound in the following manner: The flap of excess skin is elevated with a forceps or skin hook, and an incision is carried at an oblique angle from the apex of the wound toward the side with the excess skin. The flap is then undermined and laid flat. The resulting triangle of skin is trimmed, and the closure is completed (Fig. 35–45*A*). [81] [87] An alternative method consists of carrying the incision directly from the apex, in line with the wound. The flap of excess tissue is pulled over the incision while skin hooks are used to retract the extended apex of the wound. Excess tissue is excised, and the remainder of the wound is

sutured.[83] If dog-ears are present on both sides of one end of the wound, the bulge of excess tissue can be excised in an elliptical fashion, and the wound can be closed (see Fig. 35–45*B*).[87]

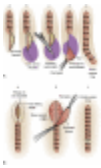

Figure 35–45 *A,* Correction of a dog-ear. *B,* Excision of bilateral dog-ears. *(A, From Dushoff IM: A stitch in time. Emerg Med 5:1, 1973. Reproduced by permission.)*

Stellate Lacerations

The repair of a stellate laceration is a challenging problem. Usually a result of compression and shear forces, these injuries contain large amounts of partially devitalized tissue. The surrounding soft tissue is often swollen and contused. Much of this contused tissue cannot be débrided without creating a large tissue defect. Sometimes tissue is lost, yet the amount is not apparent until key sutures are placed. In repairing what often resembles a jigsaw puzzle, the clinician can remove small flaps of necrotic tissue with an iris scissors; large, viable flaps can be repositioned in their beds and carefully secured with half-buried mattress stitches. If interrupted stitches are used to approximate a thin flap, small bites should be taken in the flap and larger, deeper bites in the base of the wound. A modification of the corner stitch can be used to approximate multiple flaps to a base (Fig. 35–46). Thin flaps of tissue in a stellate laceration with beveled edges may be more easily repositioned and stabilized with a firm dressing.[72]

Figure 35–46 View from above stellate laceration, showing closure with half-buried mattress stitches. For some stellate lacerations, it is best to cover with Steri-Strips and revise the scar later or, if small, excise the laceration and convert it to a linear repair. *B,* Significant soft tissue contusion with stellate lacerations. *C,* The result at 1 year. No tissue was débrided; instead, meticulous attention was paid to accurate soft tissue realignment with fine suture (7-0).

Closure of stellate lacerations cannot always be accomplished immediately, especially if there is considerable soft tissue swelling. It may be best in some instances to consider delayed closure or revision of the scar at a later date. In complicated lacerations, inexact tissue approximation may be all that is possible initially. For small stellate lacerations, it may be possible to excise the lesion totally and turn it into a linear repair.

Repair of Special Structures

Facial Wounds (General Features)

The ideal result in the repair of a facial laceration is an extremely narrow, flat, and inapparent scar. Facial and forehead lacerations that follow natural skin creases or lines will heal with a less noticeable scar than those that are oblique or perpendicular to the natural wrinkles of the skin (Fig. 35–47). In addition to basic wound management, a few additional techniques can be used to achieve satisfactory cosmetic results.

Figure 35–47 Lacerations following natural skin lines (shown here) heal with a less noticeable scar than those that are oblique or perpendicular to natural lines (or wrinkles).

Although necrosis of partially devitalized wound edges contributes to wide scars, facial skin with apparently marginal circulation may survive because of excellent vascularity. SQ fat, which in other locations may be débrided thoroughly, *should be preserved if possible in facial wounds* to prevent eventual sinking of the scar and to preserve normal facial contours. Therefore, débridement of most facial wounds should be conservative[75] (Fig. 35–48).

Figure 35–48 *A,* This woman was punched in the face, suffered a laceration of the cheek, and presented to the ED 35 hr later. The wound was not infected, but it had contracted and was beginning to heal by granulation. Under local anesthesia, the wound was opened, irrigated, minimally débrided, and the skin edges were trimmed. *B,* Using a No. 15 blade, a 1-mm-deep incision was made in the skin along the edges of the wound border. *C,* The incised edges were then cut away using tissue scissors. *D,* The wound was undermined to relieve tension on the skin. *E,* The wound is clean, undermined, and ready to close *F,* The wound was closed with 6-0 interrupted sutures that were removed in 5 days. No antibiotics were used, and only a small linear scar resulted.

A *layered closure* has long been considered essential in the cosmetic repair of many facial wounds. However, the importance of layered closures in facial wounds was called into question by Singer and associates.[91] These investigators found similar cosmetic outcomes and scar widths in facial wounds less than 3 cm in length and less than 10 mm in width that were repaired with and without deep dermal sutures. Further confirmation of these results is needed.

If a layered closure is undertaken, approximation of the dermis with a SQ stitch, or with a combination of SQ and subcuticular stitches, should bring the wound edges together or within 1 to 2 mm of apposition—close enough that the use of additional sutures seems almost unnecessary.[81] If an SQ stitch is the only stitch used to close the deeper layers, it should pass through the dermal-epidermal junction, or within 1 to 2 mm of the skin surface, without causing a dimpling effect. The stitch should be tied snugly by pulling the two ends of the suture in the same direction (see Fig. 35–19).

In cosmetic areas, the surface stitch should not be used to relieve a wound of significant tension. The surface stitch on the face is most appropriately used to match the epidermal surfaces precisely along the length of the wound. If the wound edges are separated more than about 2 to 4 mm after closure of the SQ layer, a 5-0 or 6-0 subcuticular suture can be used to eliminate the tension produced by this separation and to provide prolonged stability. An alternative approach is the use of a few *guide stitches* to hold sections of the wound together before definitive closure with surface stitches. Guide stitches allow the surface sutures to be placed with little tension on each individual stitch, they match irregular edges, and they protect the SQ stitches from disruption. The first guide stitch is placed at the midpoint of the wound, and subsequent guide stitches bisect the intervening spaces. Once the definitive surface stitches have been placed, the guide stitches, if slack, can be removed. Because a needle damages tissue with each passage through the skin, guide stitches should be used only when necessary.

In a straight laceration, better apposition during surface closure is achieved if the wound is stretched lengthwise by finger traction or with skin hooks. When the needle is placed on one side of the wound, if that side is higher than the opposite side, a shallow bite is taken. The needle is used to depress the wound edge to the proper height, after which the needle “follows through” to the other side, pinning the two sides together. If the first side entered is lower, the needle is elevated when entering the second side to match the epithelial edges.

If the skin edges are apposed closely by the SQ stitch or a subcuticular stitch, a small, shallow *“epithelial” stitch* can be used in lieu of the standard, deeper, surface stitch to correct discrepancies in vertical alignment.[74] Precise alignment of wound edges is achieved by inserting the needle as close to the edge as possible without tearing through the tissue. A 6-0 synthetic nonabsorbable suture is an excellent material for this stitch. A continuous stitch is preferable because it can be placed quickly, but interrupted stitches are acceptable. Epithelial stitches should be spaced no more than 2 to 3 mm apart and should encompass no more than 2 to 4 mm of tissue.[74] Once skin closure is complete, final adjustments in the tension on a continuous suture line are made before the end of the stitch is tied. If any level discrepancies persist, interrupted sutures or tape can be used to flatten these few irregularities. The disadvantages of epithelial stitches are that they are time-consuming and add more suture material to the wound. Level discrepancies can often be corrected with surgical tape.

Surgical tape is useful as a secondary support, protecting the surface stitch from stresses produced by normal skin movements (Fig. 35–49). Facial wounds have a tendency to swell and place excessive stretch on a surface stitch. This can be minimized by applying a pressure dressing and cold compresses to the wound after closure. Surgical tape can serve to a limited extent as a small pressure dressing. In simple, low-tension facial wounds, wound closure with surgical tape provides results that are equivalent to closure with tissue adhesive.[92]

Figure 35–49 Wound closure tape can be used to provide additional support while sutures are in place and after they are removed. This may be especially useful in cosmetic areas, such as the face.

Forehead

Although the forehead is actually a part of the scalp, lacerations in this region are treated as facial wounds. Vertical lacerations across the forehead are oriented 90° to skin tension lines, and the resulting scars are more noticeable than those from horizontal lacerations. Midline vertical forehead lacerations may result in cosmetically acceptable scars with standard closure techniques; uncentered lacerations may benefit from S-plasty or Z-plasty techniques during the initial repair or during later revision of the scar.

Superficial lacerations may be closed with skin stitches alone, but deep forehead lacerations must be closed in layers. Significant periosteal defects should be approximated before the closure of more superficial layers. If skin is directly exposed to bone, adhesions might develop that in time may limit the movement of skin during facial expressions. The frontalis muscle fascia and adjacent fibrous tissue should be closed as a distinct layer; if left unsutured, the retracted ends of this muscle will bulge beneath the skin. If the gap in a muscle belly is later filled with scar tissue, movement of the muscle pulls on the entire scar and makes it more apparent.[75]

A U-shaped flap laceration with a superiorly oriented base poses a difficult problem. Immediate vascular congestion and later scar contraction within the flap produce the “trap-door” effect, with the flap becoming prominently elevated (Fig. 35–50). This effect can be minimized by approximation of the bulk of SQ tissue of the flap to a deeper level on the base side of the wound; the skin surfaces of the two sides are apposed at the same level (Fig. 35–51). A firm compression dressing helps eliminate dead space and hematoma formation within the wound. Despite these efforts, secondary revision is sometimes necessary.[72] Often, swelling of the flap resolves over a 6- to 12-month period. Because flap elevation can be quite disconcerting, the clinician should forewarn the patient and family about a possible trap-door effect.

Figure 35–50 *A,* Elevation of a forehead flap. The “trap-door effect” is a natural healing process of elliptical or round lacerations. Patients should be advised of this phenomenon. *B,* This flap-type laceration of the forehead will heal with a puffed-up center (trap door), even under the best of circumstances. *(A, From Grabb WC, Kleinert HE: Technics in Surgery: Facial and Hand Injuries. Somerville, NJ, Ethicon, Inc, 1980. Reproduced by permission.)*

Figure 35–51 Repair of a U-shaped flap laceration with a superiorly oriented base to minimize the trap door effect. *A,* Excision of edges. *B,* Undermining. *C,* Approximation of subcutaneous tissue on the flap to subcutaneous tissue at a deeper level on the base. *B* and *C,* When a laceration in the thin skin of the forehead borders the thicker skin of the scalp, a horizontal mattress suture with an intradermal component can enhance healing by bringing tissues to the same plane. These figures show eversion of thinner skin to obtain adequate approximation with thicker scalp tissue. *D–F,* Skin closure. *(E and F, From Converse JM: Introduction to plastic surgery. In Converse JM [ed]: Reconstructive Plastic Surgery: Principles and Procedures in Correction, Reconstruction, and Transplantation, vol 1, 2nd ed. Philadelphia, WB Saunders, 1977. Reproduced by permission.)*

When a forehead laceration borders the scalp and the thick scalp tissue must be sutured to thinner forehead skin, a horizontal or vertical mattress stitch with an intradermal component can be used (see Fig. 35–51*B*).[83]

Note that even a minor forehead contusion or laceration may bleed subcutaneously and, in a few days, *produce blackness around the eyes* (Fig. 35–52). Patients should be forewarned about this. So-called raccoon eyes were once thought to represent a fracture, and although associated with fractures, this is usually a common benign finding, albeit occasionally a striking one.

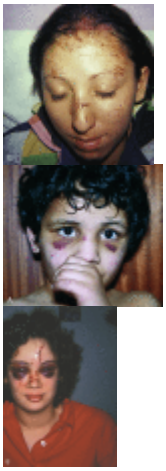

Figure 35–52 Raccoon eyes. *A,* Patients should be informed that minor forehead or nasal bridge trauma can produce benign blackness around the eyes in a few days. *B,* Most often benign, this phenomenon can be impressive. *C,* Under bilateral supraorbital nerve blocks, multiple small lacerations from this windshield injury are explored with a metal instrument and good lighting to remove tiny pieces of glass. Most superficial cuts can be left alone, others sutured with 6-0 nylon sutures (a clinical call as to which require closure).

Windshield injuries to the forehead can be problematic (see Fig. 35–52*C*) to the extent that multiple superficial cuts harbor small glass particles and the injuries do readily not lend themselves to suture closure. Supraorbital blocks can be used to anesthetize the forehead while the clinician meticulously looks for glass in each skin defect, often feeling pieces only with forceps or a small hemostat. Some pieces of glass are best felt, others are appreciated as shining objects under a good light source.

Eyebrow and Eyelid Lacerations

Jagged lacerations through eyebrows should be managed with little, if any, débridement of untidy but viable edges. The hair shafts of the eyebrow grow at an oblique angle, and vertical excision may produce a linear alopecia in the eyebrow, whereas with simple closure, the scar remains hidden within the hair. If partial excision is unavoidable, the scalpel blade should be angled in a direction parallel to the axis of the hair shaft to minimize damage to hair follicles.

Points on each side of the lacerated eyebrow should be aligned precisely; a single percutaneous stitch on each margin of the eyebrow should precede SQ closure. The edges of the eyebrow serve as landmarks for reapproximation; therefore, the eyebrow must not be shaved, because these landmarks will be lost. Shaved eyebrows grow back slowly and sometimes incompletely, and shaving them often results in more deformity than the injury itself. Care must be taken not to invert hair-bearing skin into the wound.[85]

The thin, flexible skin of the upper eyelid is relatively easy to suture. A soft 6-0 suture (or smaller) is recommended for closure of simple lacerations. Traumatized eyelids are susceptible to massive swelling; compression dressings and cool compresses can be used to minimize this problem.

The emergency clinician must recognize complicated eyelid lacerations that require the expertise of an ophthalmologist. Lacerations that traverse the lid margin require exact realignment to avoid entropion or ectropion. Injuries penetrating the tarsal plate frequently cause damage to the globe (Fig. 35–53*A*). A deep horizontal laceration through the upper lid that divides the thin levator palpebrae muscle or its tendinous attachment to the tarsal plate produces ptosis. In most cases, an ophthalmologist should repair the injury primarily. A laceration through the portion of the upper or lower lid medial to the punctum frequently damages the lacrimal duct or the medial canthal ligament and requires specialized techniques for repair (see Fig. 35–53*B*). Adipose tissue seen within any periorbital laceration may be retrobulbar fat herniating through the wound, and further evaluation is required (see Fig. 35–55*C*). The repair of lid avulsions, extensive lid lacerations with loss of tissue, and complex types of lid lacerations should be left to ophthalmologists.

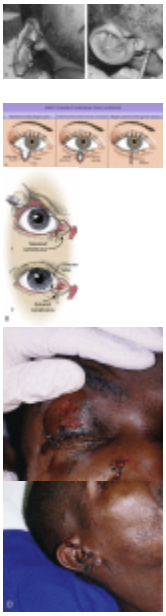

Figure 35–53 *A,* A laceration of the eyelid margin is a complicated repair usually done by an ophthalmologist or plastic surgeon. The principles of repair are demonstrated here: *1,* The suture is placed precisely in the plane of the meibomian glands at the eyelid margin, approximately 2 mm from the wound edges and 2 mm deep. This placement should provide adequate margin eversion. *2,* Partial-thickness lamellar sutures are placed across the tarsus and tied anteriorly. *3,* The anterior skin and muscle lamella are closed with fine sutures, and these are tied over the long marginal sutures to prevent corneal touch. *B,* A method of identifying and repairing the canaliculus. This repair is best left to the ophthalmologist, but the emergency clinician must recognize the potential for a canaliculus injury. *C,* Deep laceration of the left upper lid with herniation of orbital fat. For fat to prolapse, the orbital septum (and potentially the globe itself) must have been perforated. This is a wound requiring operating room exploration and repair. *D,* Lacerations of the ear require a special repair aimed at covering cartilage and preventing hematoma formation. With this through-and-through laceration of the margin of the pinna, the cartilage is trimmed just enough to allow the skin to be approximated to cover all exposed cartilage. Sutures are not used in the cartilage itself for this laceration, but the edges are approximated by skin sutures incorporating the pericondrium. The repair is easiest if the *posterior* pinna is sutured first. An ear compression dressing should be used to prevent hematoma (see Chapter 64 for discussion of anesthesia and dressing for this injury). *E* and *F,* Lacerations of the helical rim that traverse the two skin surfaces and the cartilage require a three-layer repair with accurate reapproximation of the auricular cartilage, as is done for the nose, to avoid notching. The cartilage is repaired by placing 5-0 or 6-0 clear monofilament through the perichondrium and cartilage. The skin is repaired with 6-0 or 7-0 monofilament.

Ear Lacerations

The primary goals in the management of lacerations of the pinna are expedient coverage of exposed cartilage and prevention of wound hematoma (see Fig. 35–53*D–F*).Cartilage is an avascular tissue, and when ear cartilage is denuded of its protective, nutrient-providing skin, progressive erosive chondritis ensues. The initial step in the repair of an ear injury involves trimming away jagged or devitalized cartilage and skin. If the skin cannot be stretched to cover the defect, additional cartilage along the wound margin can be removed. Depending on the location, as much as 5 mm of cartilage can be removed without significant deformity. Cartilage should be approximated with 4-0 or 5-0 absorbable sutures initially placed at folds or ridges in the pinna representing major landmarks. Sutures tear through cartilage; therefore, the anterior and posterior

perichondrium should be included in the stitch. No more tension should be applied than is needed to touch the edges together.

In through-and-through ear lacerations, the posterior skin surface should be approximated next, using 5-0 nonabsorbable synthetic sutures. Once closure of the posterior surface is completed, the convoluted anterior surface of the ear can be approximated with 5-0 or 6-0 nonabsorbable synthetic sutures, with landmarks joined point-by-point (see Fig. 35–53*E* and *F*). On the free rim, the skin should be everted to avoid later notching. Care should be taken to cover all exposed cartilage. In heavily contaminated wounds of the ear (e.g., bite wounds) that already show evidence of inflammation, the necrotic tissue should be débrided, the cartilage covered by a loose approximation of skin, and the patient placed on antibiotics. [72] [93] After a lacerated ear has been sutured, it should be enclosed in a compression dressing (see Chapter 64, Otolaryngologic Procedures).

Lacerations of the Nose

Lacerations involving the margin of the nostril are complicated and should be accurately repaired to ensure that unsightly notching does not occur (Fig. 35–54). In the medial portion of the nostril and superior columella, the lower lateral cartilages are quite close to the margin and relatively superficial. If the extent of the laceration is not recognized and repaired, the wound healing may cause superior retraction of the nostril margin. Secondary repair of the complications is difficult.

Figure 35–54 A Initially benign-appearing laceration of the left nostril of a two-year-old patient. B, However, further investigation shows a full-thickness injury with a laceration of the lower lateral cartilage. A three-layer closure with reapproximation of the cartilage was performed.

In the repair of superficial lacerations of the nose, reapproximation of the wound edges is difficult because the skin is inflexible. Even deeply placed stitches will slice through the epidermis and pull out. When the wound edges cannot be coapted easily, 6-0 absorbable sutures can be placed in the fibrofatty junction in an SQ stitch before skin closure. Because it is difficult to approximate gaping wounds in this location, débridement must be kept to a minimum. Nasal cartilage is frequently involved in wounds of the nose, but it is seldom necessary to suture the cartilage itself.

The free rim of the nostril must be aligned precisely to avoid unsightly notching. Many clinicians recommend early removal of stitches to avoid stitch marks, yet the oily nature of skin in this area makes it difficult to keep the wound closed with tape. If the wound is gaping before closure, a subcuticular stitch is recommended to provide support for a prolonged period.[94]

Lip and Intraoral Lacerations

Lip lacerations are cosmetically deforming injuries, but if the clinician follows a few guidelines, these lacerations usually heal satisfactorily.

The contamination of all intraoral and lip wounds is considerable, and they must be thoroughly irrigated. Regional nerve blocks are preferred to local injection, because the latter method distends tissue, distorts the anatomy of the lip, and obscures the vermilion border. Losses of less than 25% of the lip permit primary closure with little deformity. The following types of wounds require initial surgical consultation or later reconstructive surgery: losses of more than 25% of the lip; extensive lacerations directly through the commissure of the mouth;[93] and deep scars in the vermilion of the upper lip that later produce a redundancy of tissue.[93]

Small puncture-type lacerations heal well only if the skin is closed and the small intraoral laceration is left open (Fig. 35–55). Such injuries are common from a punch in the face when the victim's tooth lacerates the lip. *Check all lip lacerations for retained tooth fragments*. In general, small lacerations of the oral mucosa heal well without sutures. If a mucosal laceration creates a flap of tissue that falls between the occlusal surfaces of the teeth or if a laceration is extensive enough to trap food particles (e.g., ≥2–3 cm in length), it should be closed. Small flaps may be excised. Closure is easily accomplished with 4-0 Dexon or Vicryl, using a simple interrupted suturing technique. These materials are soft and less abrasive than gut sutures, which become hard and traumatize adjacent mucosa. Nylon sutures have sharp ends that are annoying and painful; thus, this suture material should be avoided inside the mouth. Muscle and mucosal layers should be closed separately. Sutures in the oral cavity easily become untied by the constant motion of the tongue. Each suture should be tied with at least four square knots. These sutures need not be removed; they either loosen and fall out within 1 week or are rapidly absorbed. [75] [95] [96]

Figure 35–55 *Check all lip lacerations for tooth fragments embedded in the wound*. *A,* This superficial mucosal laceration produced by the teeth can be cleaned, minimally trimmed, and left open to heal. Note the broken upper teeth (*arrows*), fragments may be imbedded in the laceration. Healing produces a whitish tissue that can be mistaken for infection. *B,* This extensive laceration of the mucosa requires a layered suture closure.

Small through-and-through lacerations can be thoroughly cleaned and closed in two layers (skin and mucosa). It is acceptable to leave the mucosal side open if the defect is small (Fig. 35–56). Large through-and-through lacerations of the lip should be closed in three layers. With a multilayer closure, the muscle layer is approximated with a 4-0 or 5-0 absorbable suture securely anchored in the fibrous tissue located anterior and posterior to the muscle. The vermilion-cutaneous junction of the lip is a critical landmark that, if divided, must be repositioned with precision; a 1-mm step-off is apparent and cosmetically unacceptable. The vermilion border should be approximated with a 5-0 or 6-0 nonabsorbable guide suture before any further closure to ensure proper alignment throughout the remainder of the repair (Fig. 35–57). The vermilion surface of the lip and the buccal mucosa are then closed with interrupted stitches, using an absorbable 4-0 or 5-0 suture. Finally, the skin is closed with 6-0 nonabsorbable sutures.[95]

Figure 35–56 *A,* Small through-and through lacerations made by the teeth can be irrigated and closed with skin and mucosal sutures in two layers. Small defects in the mucosa may be left open. Large through-and-through injuries and lacerations of the tongue margins require sutures to achieve anatomic healing. The muscle layer should be closed separately (with absorbable sutures) to prevent hematoma formation. In general, buried sutures are better tolerated by the patient. *B,* A lacerated tongue usually heals well without sutures, but they were placed in this patient because of a large rent in the middle of the tongue. Dexon, Vicryl, or silk sutures (avoid nylon) are ideal for suturing the tongue surface. Bleeding is usually controlled with direct pressure and local infiltration of lidocaine with epinephrine, others require deep sutures for hemostasis. Many seemingly large central tongue lacerations (such as occur during a seizure) heal well with no suturing if the margins of the tongue are intact. *C,* When a forked tongue is possible, or flaps are pronounced, the tongue requires anatomic repair. *D,* This laceration will heal well without sutures.

Figure 35–57 *A*, In the repair of lip lacerations, the first stitch (*arrow*) should be placed at the vermilion-cutaneous border to obtain proper alignment. *B*, A poorly aligned vermilion border (*arrow*) distorts the lip contour.

All lacerations that penetrate the oral mucosa should be evaluated for the presence of a tooth fragment, especially if a tooth is missing or chipped. The search should be intensified if the patient returns with an infection of a sutured wound. Probing the wound with forceps may identify fragments not seen directly in the wound. In the setting of marked facial swelling, a radiograph of the soft tissue may help identify an embedded tooth fragment.

Tongue Lacerations

Some controversy exists regarding when to suture tongue lacerations. Simple, linear lacerations, especially those in the central portion of the tongue, heal quickly with minimal risk of infection. Many small tongue lacerations that occur in children or from falls or seizures do not require sutures. In general, lacerations that involve the edge or pass completely through the tongue, flap lacerations, and all lacerations bisecting the tongue need to be sutured[94] (see Fig. 35–56). Small flaps on the edge of the tongue may be excised, but large flaps should be sutured. When dilute peroxide mouth rinses and a soft diet are used for a few days, healing is rapid. Persistent bleeding from minor

lacerations brings most patients to the hospital, and closure with deep sutures may be necessary to prevent further bleeding.

The repair of a tongue laceration in any patient is somewhat difficult, but in an uncooperative child, the procedure may prove impossible without general anesthesia. A Denhardt-Dingman side mouth gag aids in keeping the patient's mouth open. A localized area of the tongue may be anesthetized topically by covering the area with 4% lidocaine-soaked gauze for 5 minutes; the maximum safe dose of local anesthesia should be determined and exposure to greater doses avoided. Large lacerations require infiltration anesthesia (1% lidocaine with buffered epinephrine) or a lingual nerve block. If the tip of the tongue has been anesthetized, a towel clip or suture can be used to maintain protrusion of the tongue in an uncooperative patient. Further anesthesia and subsequent wound cleansing and closure are possible while an assistant applies gentle traction to the tongue.

Size 4-0 absorbable sutures should be used to close all three layers—inferior mucosa, muscle, and superior mucosa—in a single stitch, or the stitch should include half of the thickness of the tongue, with sutures placed on the superior and inferior surfaces as well as on the edge of the tongue. Sutures on the tongue frequently become untied. This problem can be avoided if the stitches are buried. Nylon sutures should be avoided because the sharp edges are uncomfortable.[75] Closure of the lingual muscle layer with a deep absorbable suture alone may be sufficient to control bleeding and return motor function to the lacerated tongue; mucosal healing is rapid.

Scalp

The scalp extends from the supraorbital ridges anteriorly to the external occipital protuberances posteriorly and blends with temporalis fascia laterally. The scalp has five anatomic layers: skin, superficial fascia, galea aponeurotica, subaponeurotic areolar connective tissue, and periosteum (Fig. 35–58*A*); however, clinically the scalp may be divided into three distinct layers. The outer layer consists of the skin, superficial fascia, and galea (the aponeurosis of the frontalis and occipitalis muscles), which are firmly adherent and surgically considered as one layer. The integrity of the outer layer is maintained by inelastic, tough, fibrous septa, which keep wounds from gaping open unless all three portions have been traversed. Wounds that gape open signify a laceration extending beneath the galea layer (see Fig. 35–58*C*). The galea itself is loosely adherent to the periosteum by means of the slack areolar tissue of the subaponeurotic layer. The galea is firmly attached to the underside of the SQ fascia and is rarely identified as a distinct layer in the depths of a wound. The periosteum covers the skull. The tissue-thin, periosteum is often mistakenly identified as the galea, but periosteum is flimsy and adherent to the skull and cannot be sutured.

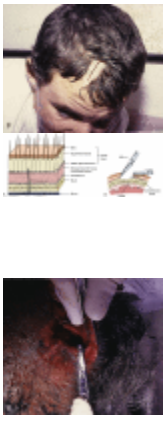

Figure 35–58 *A,* Anatomy of the scalp. The skin, superficial fascia, and galea constitute the outer layer. *Blood vessels in the fascia are the major source of the blood loss noted in scalp lacerations* (see also Fig. 35–26). *B,* To temporarily control bleeding from vessels in the fascia, the galea can be everted to compress the fascia. *C,* The galea has been transected in wounds that gape open like this one, and to achieve hemostasis and obtain the best closure, the galea should be sutured. *D,* This is most easily accomplished with the use of a long needle, forceps, and 3-0 sutures (blue nylon sutures make removal easier) *that incorporate the skin, subcutaneous tissue, and galea in a single stitch*. *Inset,* The needle is passing through the galea from the underside, having traversed all three layers on the other side of the laceration. If this technique is used, individual buried sutures in the galea are not required, and hemostasis is ensured. *At the base of this wound is the periosteum, a thin, tissue-like covering of the skull that is often mistaken for the galea*. Periosteum is not sutured. The galea is actually adherent to the avulsed flap. *E,* A good way to include all layers of the scalp in the closure is to use forceps to manipulate the tissue, so the needle can penetrate the galea as it transverses to the skin. *F,* This nongaping wound does not include the galea and can be closed with superficial sutures.

Several unique problems are associated with wounds of the scalp. Multiple scalp wounds that are hidden by a mat of hair are easily overlooked. Stellate lacerations are common in this region not only because the scalp is vulnerable to blunt trauma but also because its superficial fascial layer is inelastic and firmly adherent to the skin. Stellate lacerations pose additional technical problems in closure and have a greater propensity for infection. Shear-type injuries can cause extensive separation of the superficial layers from the galeal layer. Debris and other contaminants can be deposited several centimeters from the visible laceration; therefore, careful exploration and cleaning of scalp wounds are important. When scalp wounds are débrided, obviously devitalized tissue should be removed, *but débridement should be conservative* because closure of large defects is difficult on the scalp.

The presence of a rich vascular network in the superficial fascia results in profuse bleeding from scalp wounds. Severed scalp vessels tend to remain patent because the fibrous SQ fascia hinders the normal retraction of blood vessels that have been cut, allowing persistent or massive hemorrhage in simple lacerations. The subgaleal layer of loose connective tissue contains “emissary veins” that drain through diploic vessels of the skull into the venous sinuses of the cranial hemispheres. In scalp wounds that penetrate this layer, bacteria may be carried by these vessels to the meninges and the intracranial sinuses. Thus, a scalp wound infection can result in osteomyelitis, meningitis, or brain abscess.[94] Closure of galeal lacerations not only ensures control of bleeding but also protects against the spread of infection.

Profuse bleeding, especially from extensive scalp lacerations, is best controlled by suturing[87] (see also Chapter 34, Principles of Wound Management). Unless the vessels are large or few, ligation of multiple scalp vessels seldom provides effective hemostasis, and considerable blood loss can occur during the attempt. An assistant can maintain compression around the wound while the clinician completes wound closure. A simple procedure that often provides hemostasis of scalp wounds is to place a wide, tight rubber band or Penrose drain around the scalp, from forehead to occiput. The clinician also may control bleeding temporarily in some cases by grasping the galea and the dermis with a hemostat and everting the instrument over the skin edge (see Fig. 35–58*B*). The disadvantage of this technique is that tissue grasped by the hemostat may be crushed and devitalized.[87] If the SQ tissue also is everted for a prolonged period, necrosis can occur.

If an assistant is not available to apply direct pressure, local anesthetics containing epinephrine are sometimes effective in controlling the persistent bleeding from small vessels in scalp wounds. If bleeding from the edge of the scalp wound is vigorous and definitive repair must be postponed while the patient is resuscitated, Raney scalp clips or a hemostat can be applied quickly to the edge of the scalp wound to control the hemorrhage.

Before wound closure, the underlying skull should be visually examined and palpated in an attempt to detect fractures (Fig. 35–59). More small skull fractures are detected with the clinician's eyes and gloved finger than with radiographs. However, a common error is to mistake a tear in the galea or the periosteum for a fracture during palpation inside the wound. Direct visualization of the area should resolve the issue. In wounds that expose bone but do not penetrate the skull, prolonged exposure may leave a nidus of dead bone that may develop osteomyelitis. Exposed bone that is visibly necrosed should be removed with rongeurs until active bleeding appears.[87] Hair surrounding the scalp wound usually must be clipped far enough from the wound edge so that suturing can proceed without entangling the hair or burying it in the wound. If hairs along the wound edges become embedded in the wound, they will stimulate excessive granulation tissue and delay healing.[97] Vaseline or tape may be placed on stubborn hairs that persistently fall into the wound. Although clipping scalp hair is not popular with some patients, failure to adequately expose an area is a common cause of improper cleaning and closure of scalp wounds. Because of the extensive

collateral blood supply of the scalp, most lacerations in this area heal without problems, even after delayed treatment. Nonetheless, wound cleaning must be sufficient to avoid the devastating complication of scalp infection.

Figure 35–59 *A,* A finger and direct vision can be used to identify skull factures. Do not mistake a rent in the soft tissues as a fracture. *B,* Meticulous closure of a scalp laceration in a young person with hair is appreciated many years later when baldness occurs. *C* and *D,* This is a simple laceration that does not gape open because the galea is intact. It can be easily closed with superficial sutures or staples. Once home, the patient gently washes the hair.

Unlike most wounds involving multiple layers of tissue, scalp wounds usually can be closed with a single layer of sutures that incorporate skin, SQ fascia, and the galea (see Fig. 35–58*D–F*). The periosteum does not need to be sutured; in fact, sutures will not hold in this tissue. Separate closure of the galea introduces additional suture material into the wound and may increase infection risk. However, in extremely large wounds, separate closure may be necessary to provide a more secure approximation of the galea than can be obtained with large-needle, single-layer closure. In this situation, an inverted stitch (with an absorbable 3-0 or 4-0 suture) will “bury” the knot beneath the galea.

In superficial wounds, skin and SQ tissue should be approximated with simple interrupted or vertical mattress stitches using a nonabsorbable 3-0 nylon or polypropylene suture on a large needle. Smaller suture material should not be used because it tends to break while firm knots are being tied. The ends of the tied scalp sutures should be left at least 2 cm long to facilitate subsequent suture removal. *The use of blue nylon, rather than black, may make suture removal easier*.

With microvascular techniques, large sections of skin avulsed from the scalp can be reimplanted. The emergency clinician should use the same techniques in salvaging avulsed scalp as are used for amputated extremities.[98]

Sutured scalp lacerations need not be bandaged, and patients can wash their hair in 2 hours (Fig. 35–60). If bleeding is persistent, an elastic bandage can be used as a compression dressing. Gauze sponges are placed over the laceration to provide direct local pressure beneath the elastic bandage.

Figure 35–60 Once the scalp is sutured, the patient is encouraged to wash the hair at home that day to remove blood and debris. Prohibiting bathing with sutures in place in any part of the body has no scientific merit.

Nailbed Lacerations

Injuries to the nail and nailbed (also called the nail matrix) are common problems in emergency medicine, yet controversy exists over proper management (Fig. 35–61). As a general rule, nailbed lacerations should be repaired unless they are well approximated. An exception is the nailbed laceration that causes a simple subungual hematoma.

Figure 35–61 Anatomy of the fingernail. The fingernail rests on the nailbed, also termed the matrix. The distal nail covers the sterile matrix; the proximal nail arises from and covers the germinal matrix. The tissue adherent to the proximal dorsal nail is the eponychium (also termed the cuticle), and the potential space between the nail and the eponychium is the nailfold.

Subungual Hematomas

Subungual hematomas develop from a nailbed laceration. Some nailbed lacerations are minor and of no consequence, others portend a poor outcome unless the bed is repaired. [99] [100] *A simple subungual hematoma (even in the presence of a tuft fracture) in which the nail is firmly adherent and the disruption of the surrounding tissue is minimal is not an indication to remove the nail to search for nailbed lacerations* (Fig. 35–62).[101] Despite the presence of a nailbed laceration, a good result can be expected as long as the tissue is held in anatomic approximation by the intact fingernail. Nail trephination is discussed in Chapter 37, Incision and Drainage .

Figure 35–62 *A*, This subungual hematoma occupies most of the nail and should be drained by simple nail trephination. The injury does not require nail removal or nailbed repair, because the nail is still firmly attached to the matrix. Even though a nail matrix laceration (the source of the bleeding) is present, the cosmetic result will be excellent. The presence of an underlying digital tuft fracture does not change management. This hole is too small and did not evacuate all blood. *B*, There are two issues with this injury. First, an inadequate sized hole was placed (too small) and did not drain the subungual hematoma. All blood should be drained in the ED prior to discharge to assure proper treatment. Note the subtle ecchymosis *under the eponychium* (arrow). This can only occur if the nail base was avulsed. The base of the nail is lying just under the skin. Compare it to *A* where no blood is seen in the paronychial area since the nail base remains intact. *C*, After the hole is enlarged and the blood is totally drained, and without removing the nail, a hemostat pulls the nail forward and manipulates the base back into its proper position under the eponychium.

Large subungual hematomas associated with an unstable or avulsed nail should be sutured. Usually, the nail has to be removed completely and the nailbed repair conducted under a bloodless field (Fig. 35–63). Always use *absorbable sutures* in the nailbed so they do not have to be

removed. Paramount to a good outcome is maintaining the space under the eponychium (cuticle) as the laceration heals and the new nail grows out, a slow process.

Figure 35–63 *A,* Classic “finger slammed in a door” with forced flexion and avulsion of the base of the nail. This large subungual hematoma can be misleading, but it is associated with blood under the cuticle (*arrows*), proximal to the nail, a clue that this is not a simple injury. *B,* When the blood is drained, the extent of the injury is more obvious. *C,* The nail is carefully removed, exposing a nailbed laceration that is sutured with absorbable sutures. *D,* A drainage hole is placed in the nail (*arrow*) because it will be replaced as a temporary splint for the nailbed and to keep the cuticle space open to prevent scarring. *E,* The avulsed nail is placed under the eponychium to its base, and sutured in place for 3–4 wk while a new nail grows. This replaced nail may be removed or is pushed out by the new nail.

Partial Nail Avulsions

If the nail is partly avulsed (especially at the base) or loose, the nail should be lifted to assess and potentially repair the nailbed (Fig. 35–64*C*). If the nail is intact, it is best left in place if the nailbed laceration can be repaired (see Fig. 35–64*D-E*). The method for atraumatically removing a nail is demonstrated in Figure 35–68 .

Figure 35–64 *A,* This fingernail was avulsed at the base, a common result of having a door slam on the digit. The nail is tightly adherent to the nailbed, so it is not removed but simply replaced under the eponychium to its former position. *B,* Sutures are placed in the nail to keep it stable. This nail may simply start to grow on its own. *C,* Because this avulsed nail is unstable and there is subungual bleeding, the nail can be removed and the nailbed inspected. Any large nailbed laceration should be meticulously repaired with absorbable sutures (6-0). After nailbed repair, a drainage hole is placed in the nail, and the nail is replaced under the eponychium (cuticle) and sutured into place with sutures that incorporate the nail edge and the skin bilaterally. In 2–3 wk, the new nail will begin to push out the old nail (usually growing under it while maintaining the eponychium), and the old nail is removed. The exposed nailbed will be sensitive for a while. See Figure 35–68 for a simple technique for removal of the fingernail. *D,* A saw-induced laceration of the fingertip with an open fracture, nailbed laceration, and skin laceration. *E,* Only part of the nail was removed and the nailbed repaired through the window. The skin is closely approximated. Such injuries usually heal well with attention to detail, and infection is unusual despite the open fracture. Oral antibiotics for 5–7 days is reasonable. *F,* This nail is permanently deformed with ridges. Although crush injury to the nailbed is likely responsible for this deformity, nailbed repair might have minimized the resultant deformity.

Nailbed Repair

When the integrity of the nailbed is significantly disrupted, a rippled nail may develop (see Fig. 35–64*F*). Anatomic repair of the nailbed may minimize subsequent nail deformity. A simple nailbed laceration should be approximated with 6-0 or 7-0 absorbable sutures (to obviate the need for suture removal), generally using loupe magnification and a finger tourniquet to maintain a bloodless field (Fig. 35–65). The proximal and lateral nail (onychial) folds should be repaired first. A sturdy needle attached to a 4-0 thread is recommended for suturing lacerated nails. Needles penetrate nails most easily when they are inserted tangentially to the nail. The point of the needle carves a rigid path through the nail. Unless the entire length of the needle is allowed to follow this path as it passes through the nail, the needle is likely to bend or break. Alternatively, an electrical cautery instrument or a heated paper clip can be used to perforate the nail, thus permitting easy passage of the needle.

Figure 35–65 A laceration involving the nailbed, germinal matrix, and skin fold must be carefully approximated. First, the nail is completely removed (see Fig. 35–68). *A,* Fine, absorbable sutures are used to repair the nailbed under a bloodless field provided by a finger tourniquet. The avulsed nail (trimmed at the base) or a gauze pack is gently placed between the matrix and the eponychium for 2–3 wk to prevent scar formation. *B,* If the original nail is replaced (the best

option), it may be sutured or taped in place. A large hole in the nail will allow drainage. The old nail is gradually pushed out by a new one. If the nail matrix is replaced quickly and atraumatically, the nail may act as a free graft and grow normally. *Note*: Only absorbable sutures are used to repair the nailbed.

The exposed nailbed should be protected by reapplying the avulsed nail (best choice) or by applying a nonadherent dressing or Silastic sheet or gauze packing for approximately 2 to 3 weeks (Fig. 35–66). Reinsertion of the nail may occasionally result in infection, so cleaning the nail is recommended. After cleaning, the avulsed nail may be sutured in place or secured with wound closure tape. If only the distal portion of the nail has been avulsed, it can still be used as a temporary splint or “dressing” that protects and maintains the integrity of the underlying nailbed (Fig. 35–67).

Figure 35–66 *A,* This nail was removed and the nailbed repaired with absorbable sutures. *B,* Because the nail was macerated and unable to be replaced, gauze is used to maintain the eponychial space for 2–3 wk. A small piece of gauze is placed with forceps to gently pack open the space to prevent scar formation (diagrammed in Fig. 35–65*A*).

Figure 35–67 Repair of a distal finger laceration involving the nail and the onychial fold. In this case, the nail is still adherent to the nail matrix and acts as a natural splint. If the nail is loose or completely transected, it is prudent to remove the entire nail and then carefully suture the nailbed under direct vision. *(From Dushoff IM: Handling the hand. Emerg Med 1976, p 111. Reproduced by permission.)*

Complete Nail Avulsions

If the entire nail is avulsed but intact, it should be replaced after repair of the nailbed laceration for three reasons: (1) it acts as a splint or mold to maintain the normal anatomy of the nailbed; (2) it covers a sensitive area and facilitates dressing changes; and (3) it maintains the fold for new nail growth. If the proximal portion of the nail is not replaced, either of two complications may result: (1) longitudinal scar bands may form between the proximal nailfold and the germinal matrix, causing a permanently split or deformity of the nail; or (2) the space between the proximal nailfold and the germinal matrix of the nailbed may be obliterated within a few days.[102] Consequently, splinting should be continued for 2 to 3 weeks. The proximal portion of the traumatized nail often needs to be trimmed so that it will fit more easily in the nailfold. It is usually necessary to suture the nail in place. A replaced nail may grow normally, acting as a free graft, but often it is dislodged by a new nail. If the nail was lost or irreparably destroyed, a piece of nonadherent, petrolatum gauze (such as Adaptic or Xeroform) should be inserted between the proximal nailfold and the germinal matrix. Nails grow at a rate of 0.1 mm/day, and it requires approximately 6 months for a new nail to reach to the fingertip.

Complicated Nailbed Injuries

If the germinal matrix of the nailbed is avulsed but intact, the nail should be reimplanted using a 5-0 or 6-0 absorbable suture with a mattress stitch. [75] [103] If an open fracture exists, the matrix must not be allowed to remain trapped in the fracture line. [104]

If the nailbed is found to be extensively lacerated, it may be prudent to refer the patient to a hand surgeon, who can raise a flap of tissue extending from the proximal nailfold, explore the wound for foreign bodies, and clean under the nailbed. A fingertip avulsion that involves the nailbed, or an isolated nailbed avulsion, should not be allowed to heal on its own (i.e., by secondary intention). If the exposed nailbed is left open to granulate, it will form scar tissue that could produce a distorted and sensitive digit. Therefore, if part of the nailbed has been lost, the patient should be referred to a surgical consultant for a matrix graft. [75] [105] [106]

Wounds should be rechecked in 3 to 5 days after repair. At that time, any nonadherent material that was inserted under the proximal nailfold may be replaced, and the wound is assessed for infection. The use of absorbable suture for nailbed repair makes suture removal unnecessary. Sutures that were used to reattach the nail are removed in 2 weeks, and the old nail is allowed to fall off as the new nail grows. The value of antibiotics is unproved. All patients with nail injuries should be advised of a possible cosmetic defect in the new nail that may occur regardless of repair technique.

Removal of a Nail

If a partially avulsed or intact nail requires removal, care is taken to avoid injury to the nailbed. The nail is usually firmly attached to the bed but can be separated by advancing and opening small scissors in the plane between the nail and the bed. Once loosened, the nail can be pulled from its base with a hemostat (Fig. 35–68).

Figure 35–68 *A,* To remove a fingernail or toenail atraumatically, the blades of iris scissors are held parallel to the nailbed to avoid lacerating the matrix. A digital block is necessary. The closed blades are slowly advanced in the plane between the nail and the nailbed and then gently spread to loosen the nail. The scissors are advanced and spread in stages until the base of the nail is reached and the entire nail is loose. The nail is grasped with a hemostat and pulled from the base (*B*), exposing the nail matrix for repair (*C*). The nail can be replaced into the eponychial fold, and sutured into place as a protective measure (*D*).

Tuft Fractures

Once the nailbed has been lacerated, a tuft fracture is considered a compound fracture. The use of antibiotics for nailbed laceration is open for discussion, and no rigid standards exist. Most do well with good wound care and reasonable follow-up. Antibiotics are usually eschewed after nail trephination, even in the presence of a tuft fracture. Infection is rare, but antibiotics may be considered for significant crush or highly contaminated injuries. A tuft fracture, technically an open fracture, usually heals well. The approach to an open tuft fracture varies from formal operating room débridement and intravenous antibiotics to thorough ED cleaning and oral antibiotics with close follow-up. Splinting is protective. Search for a traumatic mallet finger in flexion (door slam) injuries.

Drains in Sutured Wounds

Drains are used primarily to keep wounds open to allow drainage of existing purulence or blood that may otherwise collect in the wound. Drains do not prevent infection. When no infection exists, and drains are used in soft tissue wounds “prophylactically,” their use is controversial in the ED setting. Drains in uninfected wounds may wick surface bacteria into the wound and impair resistance of the wound to infection.[66] Drains placed in experimental wounds contaminated with subinfective doses of bacteria behave as foreign bodies by enhancing the rate of infection, whether the drain is placed entirely within the wound or brought out through the wound.[107]

If the wound is considered at high risk for infection, instead of suturing the wound with a drain in place (in anticipation of infection), it may be more prudent to leave the wound open and consider delayed primary closure later when the risk of infection subsides. Furthermore, drains should not serve as substitutes for other methods of achieving hemostasis in traumatic wounds.

Lacerations over Joints

Lacerations over joints may enter the joint itself or injure tendons/muscle groups. It may be difficult to determine whether the joint has been violated. If so, greater attention to cleaning is required, occasionally with open débridement, but the approach varies with the joint involved. In the knee, for example, a plain radiograph may demonstrate air in the knee joint, evidence for joint penetration (Fig. 35–69).

Figure 35–69 This laceration looks benign but may involve the knee joint or quadriceps tendon. Air in the joint space on a plain radiograph proved joint space violation. A radiograph, looking for air in the joint, and/or a saline arthrogram (see Chapter 53) should be performed.

Fingertip Amputations

The treatment of fingertip amputations has undergone evolution from complicated grafts and flaps to one of nonsurgical conservative follow-up and primary healing (Fig. 35–70). If bone is not involved, a good result can be expected from attentive wound care, occasional minimal débridement, and protective dressing changes. It may take 6 to 12 weeks for healing to occur, but acceptable length, function, and sensation can be expected. A motivated patient and good follow-up are required. There is no standard that mandates long-term antibiotics for such injuries, and recommendations vary or are nonexistent. It is reasonable to provide gram-positive antibiotic coverage for 7 to 10 days, but no helpful data exist.

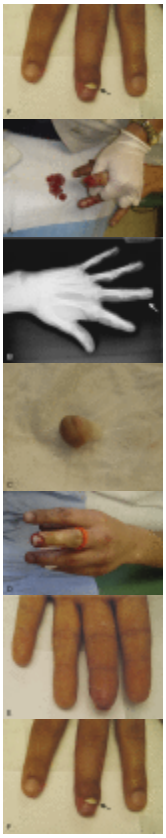

Figure 35–70 Guillotine amputation of the fingertip through the distal nail. The distal phalynx is not involved. Approaches vary widely, and referral can be made in a few days if not immediately available. Although it is tempting to replace the amputated tip (*C*), many would allow this wound to heal spontaneously, albeit slowly (8–12 wk), and not perform skin grafts or flaps. *D*, The amputated nail is placed under the eponychium and sutured into place. A rounded but shortened tip with sensation can be expected. Periodic débridement and using the nail as a splint resulted in a good final appearance. *E* and *F,* In only 4 wk, this amputation is nearly healed to the original length and contour, with only dressing changes and minimal débridements. Note that a new nail is growing (*arrow*), and the replaced nail has been removed. *G,* This macerated tip has islands of skin left and good tissue volume and will do quite well with sutures to restore basic anatomy and conservative treatment. Healing will take 4 to 5 weeks.

Distal- and Proximal-Based Flap Lacerations

There are little data in the literature concerning the care of minor flap lacerations in the ED. Large flaps, such as scalping lacerations, are best handled by a consultant, but many proximal- and distal-based flaps are treated primarily in the ED. It is important to note that these are not always simple lacerations and general wound healing principles may not apply. The major issue is one of vascularity, both perfusion pressure and venous drainage at the end of the flap and the potential for ischemic necrosis. The body has the ability to augment circulation in some flaps (Fig. 35–71*A*). Contrary to common belief, the length-to-width ratio of the flap is not the main variable in survival of the flap (Fig. 35–71*B*), rather the perfusion pressure is most critical. Intravascular perfusion pressure decreases along the length of the flap. At the distal end of the flap, intravascular perfusion pressure will become less than interstitial pressure, causing the capillaries to collapse (critical closing pressure). As edema is generated by ischemia and inflammation, interstitial pressure increases, which results in a decrease in tissue survival.

Figure 35–71 A, Vascular territories in skin flaps. Multiple perforating vessels exist and are interconnected at the periphery of their vascular territory. When some of these vessels are cut, blood supply can be replaced from nearby perforating vessels, and then tissue necrosis does not occur. B, Fallacy of the length-to-width ratio. The slope of decreasing perfusion pressure versus length does not change with incorporation of additional vessels (flap a versus flap b) with the same perfusion pressure. Flap necrosis occurs when perfusion pressure decreases below critical closing pressure of the capillary bed. C, This distal-based flap is at risk for necrosis because of impaired venous and lymphatic drainage rather than from loss of arterial supply. As with all flap repairs, it should be replaced by undermining the base to relieve tension (if possible), a compression dressing to limit movement and fluid buildup under the flap, and elevation of the extremity. Even if it undergoes only a partial take, closure can be performed in the ED. Impaired venous drainage from a proximal based flap is less problematic.

Many proximal- and distal-based flaps (Fig. 35–71*C*) may be closed in the ED and followed on an outpatient basis. Healing of a distal-based flap is hampered by loss of venous and lymphatic drainage and subsequent edema of the flap causing decreased capillary flow. Patients should be warned of the possibility of flap necrosis and the need for revision, or even skin grafting at a later date. *Partial take is better than total loss of the flap, and seemingly nonviable flaps should not be removed*. Flaps are similar to free skin grafts, and the keys to a more successful outcome include undermining the flap to relieve tension, limiting fluid buildup under the flap by a compression dressing, and decreasing movement of the flap as it heals. Minor defatting may be performed on the underside of the flap. Tissue adhesive instead of multiple sutures can be helpful.

REFERENCES

1.. Connolly WB, Hunt TK, Zederfeldt B, et al: Clinical comparison of surgical wounds closed by suture and adhesive tape. *Am J Surg* 1969; 117:318.

2.. Edlich RF, Rodeheaver GT, Kuphal J, et al: Technique of closure: Contaminated wounds. *JACEP* 1974; 3:375.

3.. Efron G, Ger R: Use of adhesive tape (Steri-Strips) to secure skin grafts. *Am J Surg* 1968; 116:474.

4.. Weisman PA: Microporous surgical tape in wound closure and skin grafting. *Br J Plast Surg* 1963; 16:379.

5.. Koehn GG: A comparison of the duration of adhesion of Steri-Strips and Clearon. *Cutis* 1980; 26:620.

6.. Rodeheaver GT, Halverson JM, Edlich RF: Mechanical performance of wound closure tapes. *Ann Emerg Med* 1983; 12:203.

7.. Rodeheaver GT, Spengler MD, Edlich RF: Performance of new wound closure tapes. *J Emerg Med* 1987; 5:451.

8.. Ellenberg AH: Surgical tape wound closure: A disenchantment. *J Plast Reconstr Surg* 1967; 39:625.

9.. Panek PH, Prusak MP, Bolt D, et al: Potentiation of wound infection by adhesive adjuncts. *Am Surg* 1972; 38:343.

10.. Emmett AJJ, Barron JN: Adhesive suture strip closure of wounds in plastic surgery. *Br J Plast Surg* 1964; 17:175.

11.. Noordzij JP, Foresman PA, Rodeheaver GT, et al: Tissue adhesive wound repair revisited. *J Emerg Med* 1994; 12:645.

12.. Singer AJ, Giordano P, Fitch JL, et al: Evaluation of a new high-viscosity octylcyanoacrylate tissue adhesive for laceration repair: A randomized clinical trial. *Acad Emerg Med* 2003; 10:1134.

13.. Bresnahan KA, Howell JM, Wizorek J: Comparison of tensile strength of cyanoacrylate tissue adhesive closure of lacerations versus suture closure. *Acad Emerg Med* 1995; 26:575.
14.. Quinn JV, Wells GA, Sutcliffe T, et al: A randomized trial comparing octylcyanoacrylate tissue adhesive and sutures in the management of traumatic lacerations. *JAMA* 1997; 277:1527.
15.. Yaron M, Halperin M, Huffer W, et al: Efficacy of tissue glue for laceration repair in an animal model. *Acad Emerg Med* 1995; 2:259.
16.. Quinn JV, Drzewiecki A, Li MM, et al: A randomized, controlled trial comparing a tissue adhesive with suturing in the repair of pediatric facial lacerations. *Ann Emerg Med* 1993; 22:1130.
17.. Bruns TB, McLario DJ, Simon HK, et al: Laceration repair using a tissue adhesive in a children's emergency department [abstract]. *Acad Emerg Med* 1995; 2:427.
18.. Simon HK, McLario DJ, Bruns TB, et al: Long-term appearance of lacerations repaired using tissue adhesive. *Pediatrics* 1997; 99:193.
19.. Maw JL, Quinn JV, Wells GA, et al: A prospective comparison of octylcyanoacrylate tissue adhesive and suture for the closure of head and neck incisions. *J Otolaryngol* 1997; 26:26.
20.. Simon HK, Zempsky WT, Bruns TB, Sullivan KM: Lacerations against Langer's lines: To glue or suture?. *J Emerg Med* 1998; 16:185.
21.. Singer AJ, Hollander JE, Valentine SM, et al: Prospective randomized controlled trial of tissue adhesive (2-octylcyanoacrylate) vs. standard wound closure techniques for laceration repair. *Acad Emerg Med* 1998; 5:94.
22.. Hollander JE, Singer AJ: Laceration management. *Ann Emerg Med* 1999; 34:356.
23.. Quinn JV, Osmond MH, Yrack JA, et al: N-2-Butylcyanoacrylate: Risk of bacterial contamination with an appraisal of its antimicrobial effects. *J Emerg Med* 1995; 13:581.
24.. Quinn JV, Maw JL, Ramotar K, et al: Octylcyanoacrylate tissue adhesive wound repair versus suture wound repair in a contaminated wound model. *Surgery* 1997; 122:69.
25.. Singer AJ, Hollander JE: Tissue adhesives for laceration closure. *JAMA* 1997; 278:703.
26.. Meiring L, Cilliers K, Barry R, et al: A comparison of a disposable skin stapler and nylon sutures for wound closure. *South Afr Med J* 1982; 62:371.
27.. Lennihan R, Macereth M: A comparison of staples and nylon closure in varicose vein surgery. *Vasc Surg* 1975; 9:200.
28.. Steele RJC, Chetty V, Forrest APM: Staples or sutures for mastectomy wounds? A randomized trial. *J R Coll Surg Edinb* 1983; 28:17.
29.. Nilsson T, FrimÀdt-Moller C, Jeppensen N: Long-term cosmetic results comparing Proximate with Dermalon skin closure. *Ann Chir Gynaecol* 1985; 74:30.
30.. Harvey CF, Hume CJ: A prospective trial of skin staples and sutures in skin closure. *Ir J Med Sci* 1986; 155:194.
31.. Khan AN, Dayan PS, Miller S, et al: Cosmetic outcome of scalp wound closure with staples in the pediatric emergency department: a prospective, randomized trial. *Pediatr Emerg Care* 2002; 18:171.
32.. Windle BH, Roth JH: Comparison of staple-closed and sutured skin incisions in a pig model. *Surg Forum* 1984; 35:546.
33.. Johnson A, Rodeheaver GT, Durand LS, et al: Automatic disposable stapling devices for wound closure. *Ann Emerg Med* 1981; 10:631.
34.. Stillman RM, Marino CA, Seligman SJ: Skin staples in potentially contaminated wounds. *Arch Surg* 1984; 119:821.
35.. Roth JH, Windle BH: Staple versus suture closure of skin incisions in a pig model. *Can J Surg* 1988; 31:19.
36.. Kanegaye JT, Vance CW, Chan L, et al: Comparison of skin stapling devices and standard sutures for pediatric scalp lacerations: A randomized study of cost and time benefits. *J Pediatr* 1997; 130:808.
37.. Shuster M: Comparing skin staples to sutures in an emergency department. *Can Fam Physician* 1989; 35:505.
38.. George TK, Simpson DC: Skin wound closure with staples in the accident and emergency department. *J R Coll Surg Edinb* 1985; 30:54.
39.. Orlinsky M, Goldberg RM, Chan L, et al: Cost analysis of stapling versus suturing for skin closure. *Am J Emerg Med* 1995; 13:77.
40.. Francis EH, Towler MA, Moody FP, et al: Mechanical performance of disposable surgical needle holders. *J Emerg Med* 1992; 10:63.

41.. Grossman JA: The repair of surface trauma. *Emerg Med* 1982; 14:220.
42.. Laufman H, Rubel T: Synthetic absorbable sutures. *Surg Gynecol Obstet* 1977; 145:597.
43.. Herrmann JB: Tensile strength and knot security of surgical suture materials. *Am Surg* 1971; 37:209.
44.. Conn J, Beal JM: Coated Vicryl synthetic absorbable sutures. *Surg Gynecol Obstet* 1980; 150:843.
45.. Macht SD, Krizek TJ: Sutures and suturing—Current concepts. *J Oral Surg* 1978; 35:710.
46.. Thacker JG, Rodeheaver G, Moore JW, et al: Mechanical performance of surgical sutures. *Am J Surg* 1975; 130:374.
47.. Westreich M, Kapetansky DI: Avoiding the slippery knot syndrome [letter]. *JAMA* 1976; 236:2487.
48.. Postlethwait RW, Willigan DA, Ulin AW: Human tissue reaction to sutures. *Ann Surg* 1975; 181:144.
49.. Webster RC, McCollough G, Giandello PR, et al: Skin wound approximation with new absorbable suture material. *Arch Otolaryngol* 1985; 111:517.
50.. Craig PH, Williams JA, Davis KW, et al: A biologic comparison of polyglactin 910 and polyglycolic acid synthetic absorbable sutures. *Surg Gynecol Obstet* 1975; 141:1.
51.. Katz AR, Mukherjee DP, Kaganov AL, et al: A new synthetic monofilament absorbable suture made from polytrimethylene carbonate. *Surg Gynecol Obstet* 1985; 161:213.
52.. Wallace WR, Maxwell GR, Cavalaris CJ: Comparison of polyglycolic acid suture to black silk, chromic, and plain catgut in human oral tissues. *J Oral Surg* 1970; 28:739.
53.. Rodeheaver GT, Powell TA, Thacker JG, et al: Mechanical performance of monofilament synthetic absorbable sutures. *Am J Surg* 1987; 154:544.
54.. Bourne RB: In-vivo comparison of four absorbable sutures: Vicryl, Dexon Plus, Maxon and PDS. *Can J Surg* 1988; 31:43.
55.. Howes EL: Strength studies of polyglycolic acid versus catgut sutures of the same size. *Surg Gynecol Obstet* 1973; 137:15.
56.. Edlich RF, Panek PH, Rodeheaver GT, et al: Physical and chemical configuration of sutures in the development of surgical infection. *Ann Surg* 1973; 177:679.
57.. In: Kaplan EN, Hentz VR, ed. *Emergency Management of Skin and Soft Tissue Wounds: An Illustrated Guide*, Boston: Little, Brown; 1984.
58.. Postlethwait RW: Further study of polyglycolic acid suture. *Am J Surg* 1974; 127:617.
59.. Stone IK, Von Fraunhofer JA, Masterson BJ: Mechanical properties of coated absorbable multifilament suture materials. *Obstet Gynecol* 1986; 67:737.
60.. Adams IW: A comparative trial of polyglycolic acid and silk as suture materials for accidental wounds. *Lancet* 1977; 2:1216.
61.. Karounis H, Gouin S, Eisman H, et al: A randomized, controlled trial comparing long-term cosmetic outcomes of traumatic pediatric lacerations repaired with absorbable plain gut versus nonabsorbable nylon sutures. *Acad Emerg Med* 2004; 11:730.
62.. Grabb WC: *Basic techniques of plastic surgery*. In: Grabb WC, Smith JW, ed. *Plastic Surgery: A Concise Guide to Clinical Practice*, Boston: Little, Brown; 1979:3.
63.. Sharp WV, Belden TA, King PH, et al: Suture resistance to infection. *Surgery* 1982; 91:61.
64.. Gristina AG, Price JL, Hobgood CD, et al: Bacterial colonization of percutaneous sutures. *Surgery* 1985; 98:12.
65.. Pham S, Rodeheaver GT, Dang MC, et al: Ease of continuous dermal suture removal. *J Emerg Med* 1990; 8:539.
66.. Edlich RF, Thacker JG, Buchanan L, Rodeheaver GT: Modern concepts of treatment of traumatic wounds. *Adv Surg* 1979; 13:169.
67.. Stillman RM: Wound closure: Choosing optimal materials and methods. *ER Rep* 1981; 2:41.
68.. Laufman H: Is catgut obsolete?. *Surg Gynecol Obstet* 1977; 145:587.
69.. Edlich RF, Rodeheaver GT, Morgan RF, et al: Principles of emergency wound management. *Ann Emerg Med* 1988; 17:1284.
70.. Towler MA, McGregor W, Rodeheaver GT, et al: Influence of cutting edge configuration on surgical needle penetration forces. *J Emerg Med* 1988; 6:475.
71.. Bernstein G: Needle basics. *J Dermatol Surg Oncol* 1985; 11:1177.
72.. Osterberg B, Blomstedt B: Effect of suture materials on bacterial survival in infected wounds: An experimental study. *Acta Chir Scand* 1979; 145:431.

73.. Wray RC: Force required for wound closure and scar appearance. *Plast Reconstr Surg* 1983; 72:380.
74.. Walike JW: Suturing technique in facial soft tissue injuries. *Otolaryngol Clin North Am* 1979; 12:425.
75.. In: Grabb WC, Klainert HE, ed. *Techniques in Surgery: Facial and Hand Injuries*, Somerville, NJ: Ethicon, Inc; 1980.
76.. DeHoll D, Rodeheaver G, Edgerton MT, et al: Potentiation of infection by suture closure of dead space. *Am J Surg* 1974; 127:716.
77.. In: Bloom W, Fawcett DW, ed. *A Textbook of Histology*, 10th ed. Philadelphia: WB Saunders; 1975:564.
78.. In: Kirk RM, ed. *Basic Surgical Techniques*, Edinburgh: Churchill Livingstone; 1978.
79.. In: Trott AL, ed. *Wounds and Lacerations: Emergency Care and Closure*, 2nd ed. St. Louis: Mosby–Year Book; 1991.
80.. Gant TD: Suturing techniques for everyday use. *Patient Care* 1979; 13(14):45.
81.. In: Peacock EE, Van Winkle W, ed. *Surgery and Biology of Wound Repair*, Philadelphia: WB Saunders; 1970.
82.. Edlich RF, Rodeheaver GT, Thacker JG, et al: *Technical factors in wound management*. In: Hunt TK, Dunphy JE, ed. *Fundamentals of Wound Management*, New York: Appleton-Century-Crofts; 1979:364.
83.. Converse JM: *Introduction to plastic surgery*. In: Converse JM, ed. Reconstructive Plastic Surgery: Principles and Procedures in Correction, Reconstruction, and Transplantation, vol 1. 2nd ed. Philadelphia: WB Saunders; 1977:3.
84.. Winn HR, Jane JA, Rodeheaver G: Influence of subcuticular sutures on scar formation. *Am J Surg* 1977; 133:257.
85.. Rodeheaver GT, Rye DG, Rust R, et al: Mechanisms by which proteolytic enzymes prolong the golden period of antibiotic action. *Am J Surg* 1978; 136:379.
86.. Jones JS, Gartner M, Drew G, et al: The shorthand vertical mattress stitch: Evaluation of a new suture technique. *Am J Emerg Med* 1993; 11:483.
87.. In: Rosen P, Sternbach G, ed. *Atlas of Emergency Medicine*, Baltimore: Williams & Wilkins; 1979:125.
88.. Myers MB, Cherry G: Functional and angiographic vasculature in healing wounds. *Am Surg* 1970; 35:750.
89.. Bernstein G: The far-near/near-far suture. *J Dermatol Surg Oncol* 1985B; 11:470.
90.. Mitchell GC: Repair of parallel lacerations [letter]. *Ann Emerg Med* 1987; 16:924.
91.. Singer AJ, Gulla J, Hein M, et al: Single-layer versus double-layer closure of facial lacerations: A randomized controlled trial. *Plast Reconstr Surg* 2005; 116:353.
92.. Zempsky WT, Parrotti D, Grem C, et al: Randomized controlled comparison of cosmetic outcomes of simple facial lacerations closed with Steri-Strip skin closures or Dermabond tissue adhesive. *Pediatr Emerg Care* 2004; 20:519.
93.. Weatherley-White RCA, Lesavoy MA: *The integument*. In: Hill II GJ, ed. *Outpatient Surgery*, Philadelphia: WB Saunders; 1980:334.
94.. Snyder CC: *Scalp, face and salivary glands*. In: Wolcott MW, ed. *Ferguson's Surgery of the Ambulatory Patient*, 5th ed. Philadelphia: JB Lippincott; 1974:153.
95.. Heintz WD: Traumatic injuries: Dealing with dental injuries. *Postgrad Med* 1977; 61:261.
96.. Horton CE, Adamson JE, Mladick RA, et al: Vicryl synthetic absorbable sutures. *Am Surg* 1974; 40:729.
97.. Zitelli JA: Secondary intention healing: An alternative to surgical repair. *Clin Dermatol* 1984; 2:92.
98.. Weinstein PR, Wilson CB: *The skull and nervous system*. In: Hill II GJ, ed. *Outpatient Surgery*, Philadelphia: WB Saunders; 1980:298.
99.. Simon RR, Wolgin M: Subungual hematoma: Association with occult laceration requiring repair. *Am J Emerg Med* 1987; 5:302.
100.. Seaburg DC, Paris PM, Angelos WJ: Treatment of subungual hematomas with nail trephination: A prospective study. *Am J Emerg Med* 1991; 9:206.
101.. Roser SE, Gellman H: Comparison of nail bed repair versus nail trephination for subungual hematomas in children. *J Hand Surg [Am]* 1999; 24:1166.

102.. Kleinert HE, Putcha SM, Ashbell TS, et al: The deformed finger nail, a frequent result of failure to repair nail bed injuries. *J Trauma* 1967; 7:177.
103.. Wolcott MW: *Hands and fingers: Part I—Soft tissues*. In: Wolcott MW, ed. *Ferguson's Surgery of the Ambulatory Patient*, 5th ed. Philadelphia: JB Lippincott; 1974:396.
104.. Matthews P: A simple method for the treatment of finger tip injuries involving the nail bed. *Hand* 1982; 14:30.
105.. Brown PW: *The hand*. In: Hill II GJ, ed. *Outpatient Surgery*, Philadelphia: WB Saunders; 1980:643.
106.. Shepard GH: Treatment of nail bed avulsions with split-thickness nail bed grafts. *J Hand Surg* 1983; 8:49.

107.. Magee C, Rodeheaver GT, Golden GT, et al: Potentiation of wound infection by surgical drains. *Am J Surg* 1976; 131:547.