Chapter 91 – Soft Tissue Trauma

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Facial injuries account for a significant number of emergency department visits each year, with 50% to 70% of these injuries having a soft tissue component.[1,2] Repair plus reconstruction of facial injuries is a highly specialized endeavor best treated by those with experience and a comprehensive understanding of the mechanism of injury, the complex anatomy of the region, and the physiologic and psychosocial impact that some injuries have. Most patients have a high level of expectation that after treatment their appearance will be largely unchanged from their preinjury state. Unfortunately, regardless of the skill of the surgeon, this is sometimes not the case because of the severity of the injury. A recent survey prioritized cosmetic outcome, more so than function, as the single most important factor to patients with facial lacerations.[3] This chapter reviews the basic concepts important in the repair and reconstruction of soft tissue injuries of the face.

EVALUATION

Evaluation of soft tissue injuries of the face begins much the same as for any injured state. The primary and secondary surveys are performed, at which time other injuries might be recognized. At times, airway protection is needed because of the complexity of the injury or massive bleeding involving the airway. Tracheotomy or cricothyrotomy is considered for patients with severe injuries that prohibit intubation or when extensive edema is anticipated, such as with severe avulsion or blast injuries of the oral cavity.

Initial stabilization occasionally requires control of hemorrhage. In the facial region, pressure dressings usually suffice for such purposes; however, larger vessel and arterial bleeding will require ligation. Blind application of clamps is discouraged because there are multiple structures of importance, such as the facial nerve, within the deep tissues.

After stabilization, a detailed examination of the craniofacial skeleton and soft tissues is performed. In addition, the superficial structures of the face (e.g., eyelids, nose, ears), deep structures such as the parotid gland and duct, facial nerves, and the lacrimal gland and its drainage system must be carefully examined in a systematic fashion. Imaging is then used to further delineate the injuries, because facial fractures are common in patients who have sustained soft tissue trauma to the face. Injuries may then be managed definitively, as in simple lacerations, or expectantly, as in crush and blast injuries. Severe crush or blast injuries are often subject to further soft tissue necrosis and leave a more significant wound than that seen at initial examination.

PREPARATION

Preparing the sites for repair and reconstruction is important for both defining the extent of injury and preventing complications. Most facial wounds should be closed within 24 hours to avoid an increased risk for infection. The rich vascular supply of the region affords the surgeon some latitude in the management of these injuries that is not seen with extremity wounds or other less vascularized regions. Perioperative intravenous antibiotics should be considered for contaminated wounds and those exposed to sinus and oral flora.

In preparation for closure, wounds should be thoroughly cleansed with sterile saline, and pulsatile irrigation systems should be considered if the wound is grossly contaminated with debris. Most wounds will be clean or clean-contaminated with little chance for infection if irrigated appropriately and empirical perioperative antibiotics are selected according to the expected contaminants. However, for grossly contaminated wounds, consideration should be given to a prolonged course of antibiotics.

After thorough preparation, the wound should be rendered hemostatic, again using local measures, suture ligation, and electrocautery when appropriate. Bipolar cautery is helpful in areas where motor nerves may be present. Débridement of the wound is accomplished when necessary, and hemostasis is achieved again. Removal of debris that is both large and small is important for healing, as well as for cosmesis of the area. Fine particles left embedded in the epidermis and dermal layers may cause tattooing, which is more difficult to manage secondarily. Aggressive removal of these particles with a nail brush, individually with a no. 11 blade, or by primary dermabrasion is recommended in most cases because secondary removal tends to be less successful and may be more damaging.

CLASSIFICATION OF INJURY AND MANAGEMENT TECHNIQUES

Types of Injury

Lacerations

Lacerations of the superficial and deep soft tissues of the face occur in an assortment of patterns and with varying complexity. The term *laceration* implies that all tissues are present but disrupted, so primary closure is usually uncomplicated. However, lacerations vary greatly, depending on the mechanism of injury. The shearing action involved in a dog bite injures the tissues in a much different manner than does the clean cut of a sharp blade. Moreover, the mechanism and severity of injury have implications with regard to the final aesthetic result. Planning closure of the laceration requires consideration of the patient's healing capabilities, tissue quality, and orientation of the laceration in relation to the relaxing skin tension lines (RSTLs).

Simple linear lacerations are easily repaired if particular attention is paid to reapproximation of the deep layers, obliteration of dead space, and orientation of the wound to the RSTLs. In simple lacerations, revision is not usually necessary unless excessive scarring occurs or if the wound directly opposes the RSTLs, which may benefit from reorientation. Stellate lacerations are generally the result of shearing, blunt, or explosive forces that crush and break the skin in multiple directions and thus naturally violate the RSTLs with multiple flaps of varying depth and irregularity. The force often results in contused and necrotic wound edges, which at times culminates in further tissue loss. A combination of blood, clot, edema, and elastic retraction of the skin edges often gives the appearance of an avulsion injury. However, after meticulous cleansing the true extent of the wound can be appreciated. Débridement of these wounds should be sparing but complete because the vascular supply is generally good and aesthetic results are best with minimal débridement.

Repair of lacerations requires precision and attention to detail when they are present in such a conspicuous place as the face. A variety of techniques are used when closing lacerations of the facial tissues (Fig. 91-1). Several basic concepts warrant discussion when considering selection of the repair technique:

1. *Tension-free closure.* A tension-free closure minimizes scarring and is achieved by ensuring that the deeper layers of the closure provide enough tensile strength to allow reapproximation of the epidermis without undue tension. Suture marks are more likely to occur when a wound is closed under tension at the epidermal level. Precisely placed sutures are helpful in preventing this problem. A well-performed deep closure will also allow early removal of skin sutures, thereby further preventing epithelialization of the suture tract, which leads to suture marks.
2. *Wound eversion.* Placement of sutures to evert the superficial layers is important in obtaining an aesthetic result. Eversion should be explained to patients so that they will understand that flattening should occur with time. Repairs that are neutral or inverted have a tendency to contract and invert further during the initial healing phases. Scarring that is depressed is much more noticeable.
3. *Anatomic placement of sutures.* Attention to anatomic layers with symmetry and precise placement contributes to a wound that heals in a more predictable and aesthetic manner.

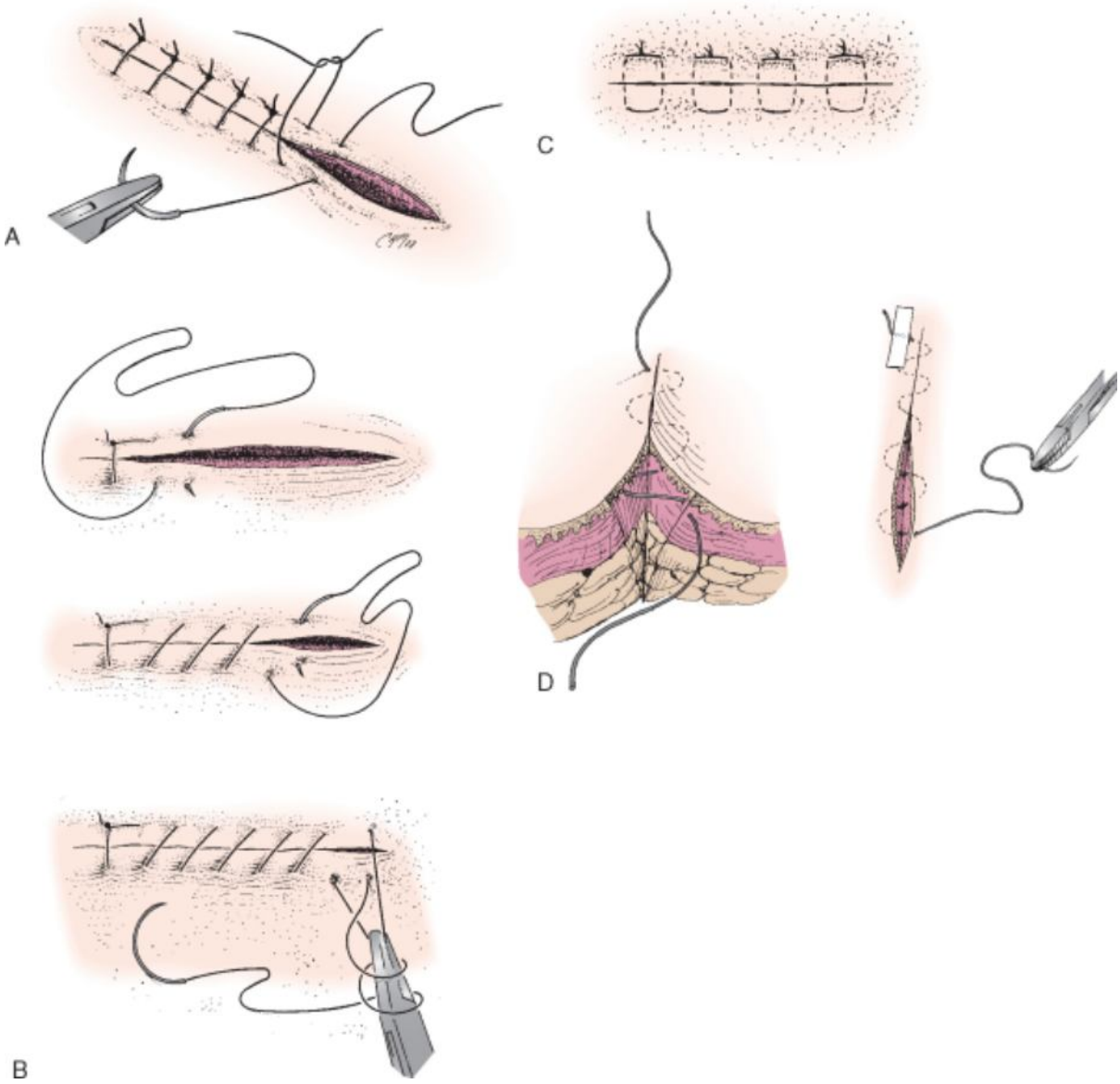

Figure 91-1 **A,** Simple interrupted sutures should be placed evenly and far enough away from the laceration edge that eversion of the skin edge is achieved. **B,** A simple continuous suture may be used for lacerations that are easily approximated. **C,** Horizontal mattress sutures are rarely used on skin but may be used for wounds that require extra strength, such as avulsions or gunshot wounds, and are expected to require revision. The surgeon must remember to avoid tying the sutures too tight or the blood supply to the margins of the laceration will be constricted. **D,** Running subcuticular sutures may be used in wounds that are well approximated and cleanly lacerated. A very aesthetic closure can be achieved if the wound edges are everted appropriately.
(Redrawn from Laskin DM [ed]: Oral and Maxillofacial Surgery, vol 1. St Louis, CV Mosby, 1980, pp 277-280.)

Contusions

Contusions exhibit bruising and swelling, as well as hematoma formation when subcutaneous vessels rupture. Contusions may indicate an underlying fracture, such as on the chin (e.g., subcondylar mandible fractures), and spectacle hematomas of the periorbital tissues (e.g., orbitozygomatic fractures). Most contusions require no treatment other than for symptomatic relief of pain and swelling, such as the application of ice, elevated head positioning, and analgesics. However, severely contused laceration edges should also be sharply débrided if it is likely that these areas may break down later because of the extent of the trauma.

Abrasions

Abrasions are superficial wounds of the skin and mucosa and involve loss of superficial epithelium with exposure of the underlying dermis or submucosa. Injuries of greater depth tend to be grouped with avulsions. Healing occurs by rapid re-epithelialization (0.5 mm/day) and typically requires only supportive care. Initial débridement and tissue cleansing may be of benefit when the skin is embedded with road debris or has been subject to powder burns. Failure to cleanse the wound may potentiate traumatic tattooing, which occurs when wound healing takes place with embedded debris. Thorough cleansing with a brush usually accomplishes this quite well, but primary or

secondary dermabrasion is sometimes necessary. Other adjuvant materials can be used to facilitate the healing process and prevent the accumulation of fibrinous plaque, such as antibiotic ointments, nonadherent dressings, and silicone gel sheeting. It should be noted that to date, few data have demonstrated significant aesthetic improvement with the use of these materials; however, in the author's experience, for large abrasions, these dressings decrease crusting and make wound care less painful.

Burns

Facial burns range from superficial to full thickness, depending on the cause and duration of the exposure. Facial burns occur in approximately one half of all patients admitted to the burn unit. Although most facial burns are superficial, deep partial-thickness or full-thickness burns do occur, and the facial anatomy is inexorably altered. Primary reconstructive efforts are focused on preservation of function with the understanding that achieving an aesthetic preinjury result is challenging. Large areas of skin loss are sometimes replaced with split-thickness skin, but it is a poor substitute for facial skin and specialized structures such as the eyelids and lips. Serial excision, local flaps, and free tissue transfer are also options, depending on the burn site.[4]

Trapdoor and Circular/Pedicled Lacerations

"Trapdoor" lacerations result in a soft tissue flap that presents healing dilemmas because of the beveled nature of the flap, which then results in a pincushion deformity. The traumatic event creates varied wound depth that often requires additional undermining of the opposing side of the laceration to properly layer the closure and evert the edges. Freshening of the edges is also commonly needed to provide opposing parallel surfaces in the same tissue plane to better distribute contractile force during the healing period. Small Z-plasties along the circumference of a trapdoor wound may be helpful in avoiding less than ideal contraction, scarring, and contour deformities; however, this technique should be attempted only when one is sure that the injury does not have a significant contusive element.

Bite Wounds

Treatment of bite wounds merits separate discussion because they are often complex wounds with features of lacerations, avulsions, and contusions concomitant with polymicrobial contamination. The crushing force delivered by the dog's jaw often results in widespread tissue injury that is grossly contaminated with up to 64 species of bacteria.[5] Antibiotics are always considered in the management of bite wounds because the contamination is usually polymicrobial in nature. Penicillins and cephalosporins are generally effective in treating the predominantly gram-positive flora.

Children younger than 10 years are most frequently the victims of facial dog bites, largely because dogs have easy access to a child's face.[6,7] The lips, nose, and cheeks are the most commonly injured structures and some the most challenging to reconstruct.[8,9] Conservative débridement and aggressive cleansing should be undertaken promptly, followed by primary closure when appropriate. Definitive reconstruction with local or distant tissue can be carried out once the zone of necrosis has become evident and the wound is sufficiently clean (Fig. 91-2). Puncture wounds are often left unclosed.

Figure 91-2 **A,** Clinical photo showing a young girl after being bitten multiple times by her dog. **B,** Magnified view showing that 50% of the superficial lip was avulsed to the commissure. **C,** Layered closure yields an aesthetic repair by closing muscle, mucosa, and skin independently. **D** and **E,** One year after the injury.

Though uncommonly encountered in the United States, rabies must always be considered with animal bites, especially with unprovoked attacks or bites from high-risk animals. Raccoons and bats carry the disease with the greatest frequency in the United States, although foxes, skunks, and wild dogs are also considered high risk. Human rabies immune globulin and vaccine are recommended for bites and exposures, irrespective of the time between exposure and treatment, unless the individual has previously been vaccinated and rabies antibodies can be detected. The vaccine takes 7 to 10 days to induce an immune response, and immunity lasts approximately 2 years. The vaccine is injected into the deltoid region at a dose of 1 mL on days 0, 3, 7, 14, and 28. Rabies immune globulin (20 IU/kg) is administered with as much of the dose as possible infiltrated in and around the wound (location permitting) and the rest given intramuscularly in the gluteal region with a needle of sufficient length to ensure intramuscular injection. The syringes and needles used for vaccine and immune globulin should be different. The tetanus vaccination status of the patient should also be ascertained, and appropriate administration of either tetanus vaccine or tetanus immune globulin should be completed (Table 91-1).[10]

Table 91-1 -- PROTOCOL FOR PROPHYLAXIS OF WOUNDS FOR TETANUS

	Clean and Minor Wounds		*All Other Wounds*	
Tetanus Toxoid Vaccination Status	Td	TIG	Td	TIG
Unknown or less than 3 doses	Yes	No	Yes	Yes
3 or more doses	No[*]	No	No[†]	No

Adapted from Diphtheria, tetanus, and pertussis: Recommendations for vaccine use and other preventive measures. Recommendations of the Immunization Practices Advisory Committee (ACIP). MMWR Recomm Rep 40(RR-10):1-28, 1991.

Td, tetanus and diphtheria toxoids; TIG, tetanus immune globulin.

* Yes if more than 10 years since the last dose.

† Yes if more than 5 years since the last dose.

Avulsions

Avulsions occur as a result of a high-energy or shearing injury, such as motor vehicle trauma, a gunshot, or an animal bite. For small wounds, adjacent tissue can be mobilized and advanced for primary closure. However, these injuries can be some of the greatest challenges to the facial trauma surgeon. Flaps that can be revascularized should be replanted when possible. When tissue loss is imminent because of the severity of trauma or delay in treatment, avulsive injuries may benefit from a period of observation with serial débridement and dressing changes to ensure adjacent tissue viability before definitive reconstruction. Typically, wound necrosis is evident within a few days to weeks and reconstruction can then be completed. Avulsion of special structures such as the ear and scalp may require salvage with microvascular replantation techniques. Other large defects may call for the recruitment of distant pedicled or microvascular flaps after a period of observation and expectant wound management (Fig. 91-3). Finally, primary skin grafting, followed by secondary revision (i.e., tissue expansion with local flap rotation, serial graft excision, free flap reconstruction), continues to remain a good option in many complex wounds rather than depending on healing by secondary intention, which can lead to extensive scar contraction.

Figure 91-3 Massive facial avulsion involving the eyelids, nasal complex, upper and lower lips, and check after a motor vehicle crash in which this young child was not restrained. It is important to note damage to the globe, lacrimal system, facial nerve, salivary glands, and nasal drainage system for the sinuses in such complex injuries. Composite soft tissue grafting with microvascular techniques can be used either immediately or as a staged procedure.

Gunshot Wounds

Firearm injuries are common in countries that do not have strict gun control laws. A detailed discussion of the complexities of gunshot wounds is beyond the scope of this chapter, but the basic concepts presented here are important to recognize. A variety of injury patterns can be expected depending on the type of projectile. Low-velocity weapons such as pellet guns may cause limited local damage, whereas high-velocity projectiles may disrupt tissue along a defined vector. Various projectiles are designed with differing degrees of soft and hard tissue damage capability. Most of these injuries depend on how the projectile passes through tissue, including tumble, yaw, and other physical properties. Projectiles with higher velocity and a propensity to twist, fragment, and turn through tissue will produce more significant damage. Additionally, bone and tooth fragments become secondary projectiles that tend to increase the field of injury. The blast injury that occurs with the initial trauma varies according to these projectile characteristics but is often not apparent for days after the injury. The greater the injury capability of the projectile, the longer the surgeon should wait to consider definitive reconstruction. A certain degree of additional tissue necrosis will occur in a delayed fashion, depending on these characteristics, and expectant wound management is advisable. The ultra high-velocity weapons used in combat may cause particularly devastating injury to the facial soft tissues and skeleton. Reconstruction may include local, regional, or free tissue flaps, depending on the degree of injury. Revision may be expected in more significant injury.

Several key concepts are important to remember when closing complex wounds such as gunshot wounds:

- Layered closure prevents tension on the wound at the epidermal level, which will decrease scarring potential. All dead space should be closed with an anatomically layered closure. This is particularly important for the random-pattern flaps that may be developed as rotation or advancement flaps for local closure of small to medium-sized defects.
- Débridement is important for successful healing of the wound, but the surgeon should remember that because the face is very vascular, aggressive débridement is often not necessary. Tissues that are minimally contused do not generally need to be débrided. Small irregular edges should be excised and simplified in most cases.
- RSTLs are helpful in planning local flap recruitment. A more aesthetic result is obtained when the flaps can be designed to allow incisions, backcuts, and dog-ear repairs to fall within the RSTLs.

Anesthesia

In most instances, local anesthesia, when appropriately applied, is sufficient to allow complete closure of the wounds typically seen in the emergency department. Particularly complicated wounds or wounds in small children will often require sedation or general anesthesia. The benefits of general anesthesia in the operating room are evident when caring for complicated wounds because better instrumentation and lighting are readily available.

It is helpful to be proficient in local anesthetic blocks of the trigeminal system when repairing wounds of the face. Frequently, large areas can be profoundly anesthetized when blocking the region with a precisely placed local anesthetic. Generally, 1% lidocaine with 1:100,000 epinephrine is used and provides profound anesthesia in the area of repair. One must consider the maximal allowable dose in individuals who require other procedures concurrently or have extensive lacerations requiring multiple injections. Such consideration is particularly important in small children because it is not difficult to reach the maximal allowable dose with what seems to be a small volume of anesthetic. Nerve blocks can be helpful in these patients inasmuch as less volume is required to achieve profound anesthesia. One must also make sure that facial nerve function has been thoroughly evaluated when anesthetizing lateral face wounds, because exploration and primary repair may be warranted before wound closure.

Suture Materials

A variety of sophisticated materials are available to the surgeon for repair and reconstruction of soft tissue injury, and understanding their capabilities and handling characteristics is important (Table 91-2). Both nonresorbable and resorbable materials are available in a variety of sizes and with a variety of needle types. Deeper layers are best reapproximated with longer-lasting resorbable suture that is braided. Suture strength and the rate of degradation should anticipate forces placed on the wound particular to the anatomic locale and provide enough tensile strength to support the wound and allow complete healing. Subcutaneous and deep dermal sutures are best placed with the knot buried and the use of resorbable suture. Skin is best reapproximated with nonresorbable monofilament suture at least 5-0 or smaller in size. It is often convenient to consider resorbable material in pediatric patients because they may require an additional anesthetic or involuntary restraint to remove simple sutures. These materials may have slightly more reactivity and cause additional inflammation at the healing site. Staples may be used in less cosmetic areas such as scalp wounds.

Table 91-2 -- COMMONLY USED SUTURE MATERIALS FOR FACIAL REPAIR AND RECONSTRUCTION WITH SOME OF THEIR IMPORTANT CHARACTERISTICS

Suture	Absorbable	Common Site of Use	Pearls
Polyglycolic acid	Yes	Deep layers of closure such as fascia	Excellent handing characteristics because it is a braided suture; moderate reactivity; offered with antibiotic treatment; smaller suture may lose tensile strength at about 2 weeks; bury the knots
Polyglecaprone	Yes	Deep and subcuticular closure; fine suture may be used for skin	Good handing characteristics for a monofilament suture; moderate reactivity; very small sizes such as 5-0 can be used for key sutures on skin because resorption is rather quick
Chromic gut	Yes	Mucosal repair; very fine suture may be used for skin closure	More reactivity and less desirable handing characteristics; monofilament suture; very useful for mucosal closure because it is resorbed quickly
Nylon	No	Skin closure or subcuticular pull-out suture	Monofilament suture that requires removal; minimal reactivity; easily seen for removal because of its black color

Suture	Absorbable	Common Site of Use	Pearls
Polypropylene	No	Skin closure or subcuticular pull-out suture	Monofilament suture that requires removal; excellent handing characteristics; minimal reactivity; easily seen for removal because of its blue color

Needles come in a variety of shapes and sizes as well. The skin is best sutured with a cutting needle to minimize trauma to skin during placement. Most deep tissues and mucosa are best approximated with tapered or combination needles to minimize trauma to tissues. Keratinized mucosa such as the palate or gingiva may be closed with a cutting needle.

Adequate instrumentation and lighting are essential for accurate surgical closure. Delicate needle holders and fine pickups are helpful to approximate tissue in a detailed and atraumatic fashion. Fastidious tissue handling is also crucial for an aesthetic closure. Excessive epidermal handling with tissue forceps can result in crush injury to the skin edges. Picking up tissue in the deep and subcutaneous planes minimizes trauma to the epidermis and improves superficial healing. The surgeon should be comfortable with all forms of hand and instrument ties, as well as suture-placing techniques. Mastering these techniques is essential to providing a superior closure.

Cyanoacrylate Tissue Adhesives

When applied carefully, the use of tissue adhesives for closure of wounds is both cost-effective and efficient. Their efficacy for strength of closure and cosmesis has been demonstrated in the literature.[11,12] Two main cyanoacrylate-based tissue adhesives are available for traumatic wound closure, butyl-2-cyanoacrylate (Histoacryl, Braun, Germany) and 2-octylcyanoacrylate (Dermabond, Ethicon, Somerville, NJ). The 2-octyl polymer was created to avert some of the shortcomings of its predecessor. Butyl-2-cyanoacrylate maintains only 10% to 15% of the wound strength of 5-0 monofilament on closure day 1; however, its strength was equivalent on days 5 to 7. 2-Octylcyanoacrylate, in contrast, has roughly three times the three-dimensional breaking strength of butyl-2-cyanoacrylate, which compares more favorably with conventional wound closure.

Cyanoacrylate tissue adhesive can be used topically to close skin lacerations on its own, or it can be used along with deep sutures. Deep dermal sutures can be placed to obtain proper wound edge eversion. As with suture techniques, everting the wound edges is essential to the cosmetic success of skin closure with tissue adhesives, because eversion helps alleviate the effects of scar widening. Skin apposition should be maintained with forceps or fingers regardless of whether deep sutures are used during the application. For optimal results, multiple thin layers should be applied over the epidermis and allowed to dry for approximately 10 to 30 seconds. This technique prevents pooling and running of the tissue adhesive, which can lead to significant complications in certain areas of the face (i.e., eyes, ears), and it also diminishes the heat transferred to tissues during polymerization.[12–14] It should be noted that this material is not recommended around the eyelid tissues because unintended adhesion of the eyelid or other critical structures has occurred. Tissue adhesive materials are not viscous and tend to run quite easily. For this reason, moist gauze should be present to remove excess when necessary.

Postoperative Wound Care

A carefully crafted dressing is important both for protection of the wound from contaminants and for care of the wound. In most instances, a minimal dressing is used that may consist of small bandage strips or antibiotic ointment placed several times a day for 1 week. Complex wounds may require extensive dressings, retention sutures, or temporary bolsters. Pressure dressings may be helpful in certain types of scalp wounds to avoid hematoma formation, or drains may be used in areas of potential dead space. Ear lacerations often require the placement of bolster dressings to help avoid hematoma formation. Tarsorrhaphy and Frost sutures may be placed in eyelids to prevent unwanted contraction and disruption of certain repairs.

After the acute healing phase has passed and a small amount of intrinsic strength has developed in the wound, early suture removal is possible, and meticulous care of the wound continues. Sutures can generally be removed in 5 to 7 days for most facial wounds. Early removal prevents hatchmarking, although wounds that are under some tension may require a longer retention period. Alternatively, every other suture can be removed at an early visit. Additional adhesive bandaging may be used to reinforce and protect the wound for an additional week or two. Once the sutures are removed, the wound may be gently massaged several times daily to help hasten maturation and soften any hypertrophic or uneven subcutaneous scarring. Supplemental material such as vitamins, silicone gels, or lotions may help improve scarring in some instances, but positive outcome data are lacking. Use of sunblock is encouraged because excessive exposure to ultraviolet radiation can alter the pigmentation and leave the scar more visible. Sunblock that is nonirritating to the eyes is important for upper facial wounds.

Revision

Secondary reconstruction of soft tissue injuries of the face is beyond the scope of this chapter, but it is important

to discuss the likelihood of secondary surgery with patients who have endured trauma. Scar revision is inevitable in some patients who either do not exhibit optimal healing or have scarring as a result of a more severe injury. In general, most revisions are best performed after 1 year unless extremely unfavorable aesthetics or functional concerns are present. Scar maturation continues beyond the initial months of healing and will continue to improve the appearance of many scars without significant intervention in the first year. A long-term follow-up schedule should be discussed with patients to ensure the best result, as well as their own personal satisfaction.

SPECIAL CONSIDERATIONS

Periocular Injury

When evaluating periocular soft tissue trauma, one must first exclude underlying globe injury and cranio-orbital fractures. In addition, when evaluating the upper and lower eyelids, one should consider the location, depth, tissue loss, function, and presence of foreign bodies. Measurements of canthal distances and symmetry are important to assess medial or lateral canthus detachment. Primary reconstruction of these specialized orbital injuries is usually more successful than secondary reconstruction.

If the injury is linear in nature, repair consists of anatomic reapproximation of the tissue layers. The eyelid margin, the eyelash line, the gray line, and the meibomian glands are conventionally used as landmarks to direct the operative repair. The first sutures are placed along the lid margin or gray line to initiate proper alignment, as well as to provide traction for the remainder of the closure. Size 6-0 silk or nylon is used for this purpose, with the ends cut long and tied down under adjacent skin sutures to avoid corneal abrasion. The tarsal plate and pretarsal muscles are closed with 6-0 Vicryl, and the skin is closed with 6-0 nylon. The conjunctiva may be left unclosed if the wound edges are well apposed. It is essential to ensure proper alignment of the tarsus and eversion of the lid margin to avoid a notched appearance of the lid.

Complex lacerations and eyelid avulsion injuries may appear to have what seems to be significant tissue loss; however, once cleaned and thoroughly evaluated, they can usually be closed primarily. Should the cornea become exposed, *immediate* attention is required to keep it moist until definitive lid repair has been accomplished (Fig. 91-4). It is important to reposition the injured tissues so that the canthi, orbital septum, and levator aponeurosis are restored to the best positions possible (Fig. 91-5). When tissue loss has occurred, every effort should be made to preserve existing structures, even when their appearance is marginal. Avulsed tissues can often be used as composite or full-thickness grafts for the reconstruction of partial-thickness defects. Full-thickness defects of up to one half the eyelid may be closed primarily with the use of releasing incisions. Tissue loss of greater than one half the eyelid may require a cheek advancement flap, lid switch procedure, or skin graft.

Figure 91-4 **A** to **C,** Clinical photos of a young girl who was struck by a fire hose that had become dislodged from a moving fire truck with disruption of the periorbital tissues and an avulsed zygomaticomaxillary complex (ZMC) fracture. After plating the ZMC on the back table, the wound was closed and all the periorbital structures were repositioned with minimal débridement. **D** and **E,** Three months after the repair, the wound has the typical erythema associated with ongoing tissue remodeling, and all her orbital and periorbital structures are functioning well.

Figure 91-5 **A** and **B,** Preoperative photos of an Amish boy with a chainsaw injury to the right upper lid and brow. The orbital musculature and septum are disrupted, the tarsus is intact, and there is minimal tissue loss. **C** and **D,** Primary débridement and closure are achieved with anatomic repositioning of the components of the upper eyelid. Prompt lubrication is important to keep the cornea moist and avoid abrasion.

Any disturbance in the lacrimal system can lead to an excess or deficit of tear availability, which may then result in corneal damage or visual changes. Both the secretory and excretory aspects of the lacrimal system are vulnerable to injury. The secretory component consists of the lacrimal gland, the conjunctiva, and the minor glands of the eyelid. A tear film is produced and distributed over the cornea primarily by the action of the eyelids and then drains medially. Drainage occurs via the lacrimal canalicular system, the lacrimal sac, and the nasolacrimal duct. The canaliculi are absolutely crucial for normal tear drainage and are the most frequently injured structures of the lacrimal system.[15]

Injury to the lacrimal canaliculi should be suspected with any laceration medial to the puncta. The wound should be evaluated by direct inspection, probing, or direct or indirect instillation of visible fluids into the canalicular system. This should allow thorough evaluation of the patency and continuity of the canaliculi by the presence or absence of injected fluid in the wound versus the nose. Fluorescein is most commonly used for this purpose.

Injuries to the superior canaliculus rarely cause epiphora; however, most transections of the inferior system should be repaired, because the inferior canaliculus is responsible for the majority of normal tear drainage. Primary repair of canalicular injuries includes careful probing and intubation of the canaliculi under magnification. The proximal canaliculus is often difficult to identify and may be localized by probing the uninjured punctum and then passing the probe medially. The probe can then be passed through the wound into the distal aspect of the canaliculus and through the injured punctum. Intubation is frequently performed with either a monocanalicular or bicanalicular silicon tube, which is left in place for 3 months until re-epithelialization of the canaliculus has occurred and the

pericanalicular inflammation has resolved.[15,16] Once this is complete, pericanalicular sutures are placed and the lid margin is closed.

Facial Nerve Injury

Traumatic injury to the extracranial facial nerve should be suspected when lateral facial lacerations and parotid injuries are recognized. When possible, it is important to obtain an accurate examination of the cranial nerves before the administration of local anesthetic, sedative medications, or paralytics. Unfortunately, this may be difficult in patients who have suffered multisystem trauma or significant neurologic injury. Focal deficits in facial tone and expression may help localize the damaged segment. This also facilitates appropriate exploration at the time of wound closure. As a general rule, facial nerve injuries distal to a vertical line dropped from the lateral canthus of the eye are not repaired because they are too small for successful coaptation. Microsurgical repair of the nerve can be successfully performed within 2 to 3 weeks of the original injury. However, immediate repair may be easier for the surgeon because stimulation of the distal axons before wallerian degeneration aids in identification of the nerves. Should the repair be delayed as a result of severe systemic injuries, the nerve endings should be marked with suture at the time of débridement (Fig. 91-6).

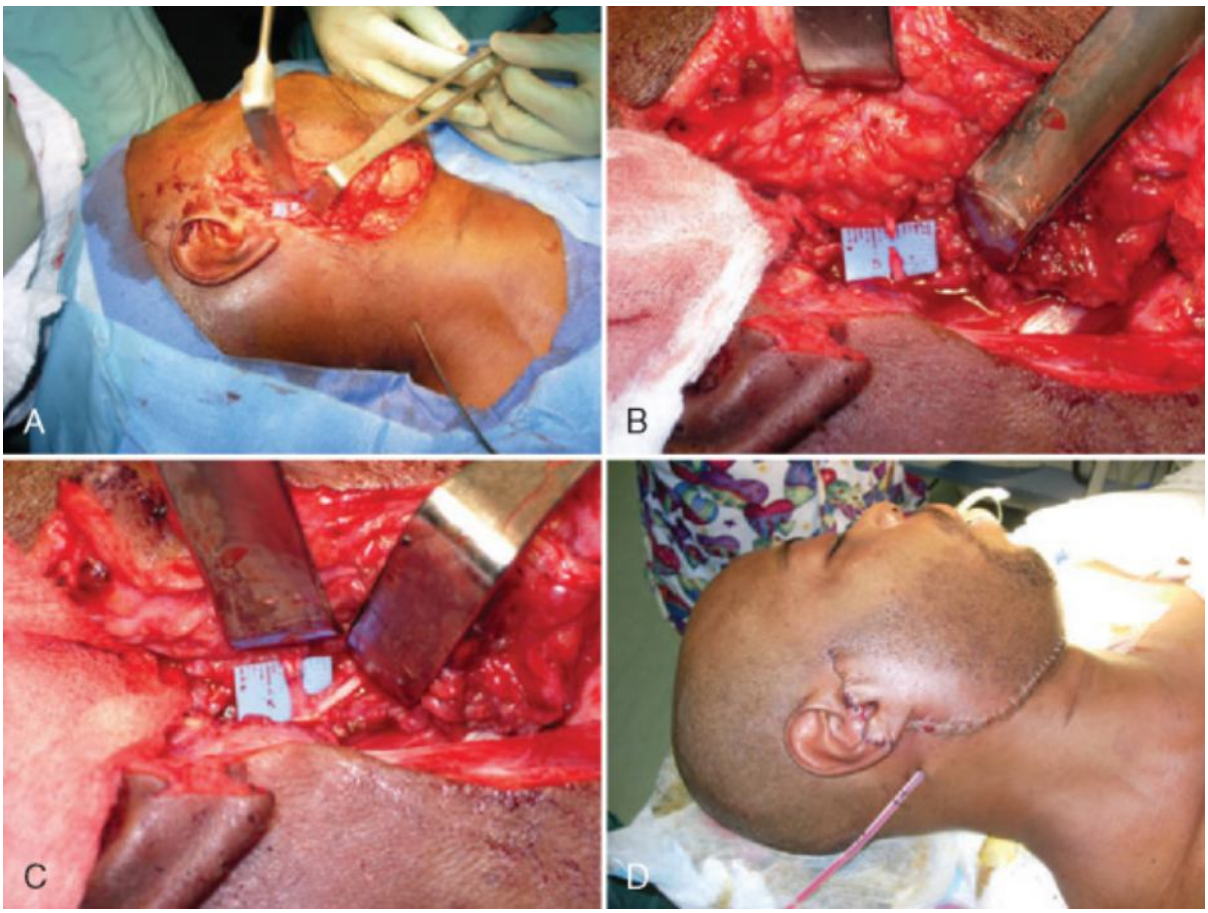

Figure 91-6 **A,** A stab injury has severed the superior division of the facial nerve. **B** and **C,** Isolation of the nerve under high-power magnification allows excellent visualization of the proximal and distal stumps and primary repair of the nerve. **D,** Closure over a suction drain helps avoid hematoma, seroma, and sialocele formation.

Options for repair of extracranial facial nerve injury include primary neurorrhaphy, graft neurorrhaphy, and nerve transposition. Occasionally, superficial parotidectomy must be performed to adequately mobilize the proximal and distal nerve branches for an optimal tension-free repair. Concomitant gland and duct injuries should be addressed at this time to avoid the formation of a sialocele, tissue inflammation, and impaired healing, which may adversely affect the outcome of the nerve repair. Regardless of the procedure chosen, the repair is best performed under magnification. In preparation for the repair, excision of the proximal and distal nerve stumps to provide healthy fascicles should be undertaken.

Common nerve donor sites for reconstruction of the facial nerve include the great auricular nerve, the sural nerve, and the median antebrachial cutaneous nerve. Selection of the donor site should be based on the graft dimensions needed for the particular repair and the patient's acceptance of the notion that anesthesia will be experienced at the donor site. Finally, nerve transposition of the hypoglossal nerve or an intact branch of the ipsilateral facial nerve

has proved useful in select cases. One drawback of this technique includes mass movement of the face rather than detailed individual muscle group movement.[17,18]

Parotid Gland and Duct Injuries

Lacerations of the gland parenchyma are managed by layered closure (to include the capsule of the gland) whenever possible. Sialocele is an infrequent complication, especially when the drainage mechanism of the gland is intact. Persistent sialocele should alert one to the possibility of a missed duct injury and warrants re-exploration. In addition to the facial nerve, the parotid gland and Stenson's duct are particularly susceptible to lateral facial injuries and present special management challenges. Causes of parotid injury are numerous but frequently involve slash or stab wounds to the cheek, glass injuries from bottle fragments or automobile windows, and avulsive and blast injuries. Failure to recognize and appropriately manage significant gland and duct injuries may result in a sialocele or salivary-cutaneous fistula.

The anatomic course of the duct can be approximated externally by a line extending from the tragus of the ear to the midpoint of a vertical line drawn from the alar base of the nose to the vermilion of the upper lip. Thorough exploration should be undertaken and both ends of the severed duct identified. Retrograde cannulation of the duct may confirm the presence of injury, as well as identify the distal stump. The proximal portion may be identified by milking saliva from the gland. The proximal duct is large, thus making it amenable to identification with loupe magnification. When possible, the duct should be repaired primarily over a stent. The stent is then left in place for several weeks to encourage re-epithelialization. Should there be a continuity defect involving the duct, a vein graft may be used in an attempt to re-establish continuity. Another approach is to divert the remaining proximal duct posteriorly in the oropharynx to develop a new drainage site. Alternatively, the proximal stump may be tied off in the hope that the gland will eventually atrophy. Pressure dressings and antisialagogue medications may be useful as adjuncts.

External Ear Injury

The ear is highly vascular and will often survive on a narrow pedicle despite severe trauma. Therefore, the surgeon should be conservative when débriding tissue in this area. For simple lacerations, the ear has the advantage of well-defined landmarks that are easily reapproximated (Fig. 91-7). Layered closure with fine, undyed, slowly resorbable suture to approximate and support the cartilage framework and with fine monofilament suture to close skin is appropriate in this situation. Auricular hematomas secondary to blunt trauma are commonplace and should be drained acutely lest the patient be left with a “cauliflower ear” deformity. The incision for drainage should be placed in a recessed portion of the pinna over the hematomas. A bolster dressing is placed with transauricular sutures to obliterate the resultant dead space and assist in redraping the soft tissue.

Figure 91-7 **A,** Slash injury with disruption of the facial, ear, and scalp tissues. Only the superficial layers were affected. No parotid duct or facial nerve injury occurred. **B,** Primary repair of the laceration in anatomic layers. **C**, One week after repair once the sutures were removed. *(Courtesy of Domenick Coletti, DDS, MD, Baltimore, MD.)*

Avulsed segments that are no greater than 1.5 cm may be suitable as composite grafts. If the segment is not available, wedge excision and primary closure may be performed. Avulsions of the entire ear may be reattached with the use of an operative microscope if the time until replantation is short and the vessels are minimally damaged. Alternatively, the cartilage can be de-epithelialized and buried within the dermis to preserve the tissue for secondary reconstruction. Rarely do buried cartilage replantations or total auricular reconstructions live up to the cosmetic expectations of the patient, except in the hands of exceptionally skilled surgeons with considerable experience. Implant-supported prostheses are very aesthetic but may induce chronic irritation associated with the abutment-skin interface.

Nasal Injuries

Injuries to the nose range from simple lacerations to avulsions and may involve the underlying bone, cartilage, and mucosa. The injury frequently occurs at the junction of the bony and cartilaginous skeleton and is often much more extensive than apparent on the surface. As with other structures of the face, tissues that appear somewhat questionable should be preserved and used as pedicled flaps or composite grafts. Significant partial nasal avulsions may survive, provided that one of the multiple vascular pedicles remains intact (Fig. 91-8). Mucosa should be closed when possible, and nasal cartilage should be carefully repositioned and sutured to preserve the tip projection and support. The skin envelope is closed to protect the underlying cartilage. For avulsion injuries and full-thickness nasal skin injuries, composite grafts and full-thickness skin grafts from the ear and periauricular skin may be considered. Before entertaining primary reconstruction (e.g., local flaps and grafts), one must ensure a clean viable wound bed with minimal risk of infection.

Figure 91-8 **A** to **C,** Preoperative views of a young boy who sustained a dog bite injury to the nasal complex with near avulsion of the external nose and upper lip. The upper lip is pedicled on the superior labial arteries and the injury has penetrated through the oral cavity to the maxillary vestibule. **D,** After reconstruction. **E** and **F,** Three weeks after the repair, the child is shown with the typical erythema of the wounds and excellent healing.

Scalp Injuries

The scalp encompasses the area from the supraorbital rims anteriorly to the occiput posteriorly and is composed of five distinct layers. The total area of the scalp is quite substantial and the tissue highly vascular. Significant blood loss can occur in association with scalp injuries and should be replaced aggressively with isotonic fluids or blood products. Hemostasis is often of primary concern when managing scalp wounds and can largely be achieved with the judicious use of clamps and hemostatic sutures. Acutely, digital pressure and large-volume sterile saline injection directly applied to the wound can achieve temporary hemostasis until the proper instrumentation is available for definitive surgical control.

Primary closure of the scalp is easily accomplished when there is no significant tissue loss. The scalp should be closed in two layers: 2-0 or 3-0 Vicryl sutures for the galea, followed by 3-0 monofilament or staples for skin closure. The galea is firmly affixed to the more superficial tissues and, when closed properly, provides appropriate scalp contour, relieves tension, and aligns the skin edges. A suction drain is recommended for large wounds or when significant undermining has taken place.

The tissues of the scalp, in addition to being highly vascular, are quite thick and equally inelastic. Mobilization of local flaps requires wide undermining and galeal scoring (Fig. 91-9). Care must be taken to preserve the more superficial subcutaneous vessels when extensive scoring is necessary. Just as challenging is the recruitment of

hair-bearing tissue to reconstruct larger avulsion defects. Free tissue transfer or pedicled flaps must often be used to provide adequate surface coverage while keeping in mind that future tissue expansion and local flap reconstruction may be necessary to provide optimal cosmesis. Smaller defects may be reconstructed with local hair-bearing flaps or skin grafting (or both), followed by serial excision. One issue to be considered is the presence of intact periosteum. When periosteum is present, a defect can simply be skin grafted and reconstructed at a later date; however, if periosteum is lost, the exposed cranium should be covered with local tissue raised in the supraperiosteal plane or with distant tissue. When local or free tissue is not an option, multiple burr holes can be placed in the diploic space to encourage the formation of granulation tissue and subsequent outer table coverage. This wound bed is then maintained and optimized with dressing changes until it is ready to accept a split-thickness skin graft.

Figure 91-9 **A**, Preoperative view of a scalp wound with a significant crush and avulsive injury to a portion of the temporal scalp. **B**, The wound is shown after excision and débridement of nonviable tissue. **C**, A local advancement flap is mobilized, and galeal scoring assists in advancement of the scalp. **D**, Closure of the wound with minimal tension and a suction drain minimizes complications and achieves complete reconstruction in one stage.
(Courtesy of Domenick Coletti, DDS, MD, Baltimore, MD.)

Lip Injuries

The lips are a key focal point in the central portion of the face and require meticulous repair to avoid the obvious stigmata of traumatic injury. It is crucial that a layered anatomic closure be performed to ensure proper function and maximize aesthetics (see Fig. 91-2). Like other facial structures, there are anatomic landmarks to guide precise repair of the lips, including the wet-dry line, the white roll, Cupid's bow, and the commissure. For injuries in which the vermilion has been lacerated, tattooing these landmarks with methylene blue may help ensure appropriate repositioning, especially because edema and hemorrhage make identification of these structures more difficult. In addition to proper repositioning of the external lip, it is also imperative to achieve realignment of the muscle. If the muscle is not properly repaired, bulging may be evident on either side of the repair, as well as shortening and notching of the lip.

In cases in which a portion of the lip has been avulsed, reconstruction varies greatly, depending on the size of the defect and which aspects of the lip are involved. For instance, if only a portion of the vermilion is missing, consideration should be given to whether an improved aesthetic result will be gained by excising a wedge of the lip and performing primary closure or repairing the lip as it is. The best results and ease of anatomic alignment are

usually obtained when the laceration is oriented at 90 degrees to the lip margin. For defects of one third to one half the width of the lip, primary closure is possible but may result in microstomia. Options include a variety of advancements, rotations, and local flaps that are beyond the scope of this chapter. As with all facial injuries, the choice of primary versus secondary reconstruction is based on the extent and the mechanism of the injury. If primary reconstruction is not possible, mucosa can be closed to skin until definitive reconstruction is performed.

SUMMARY

Management of soft tissue trauma can be challenging and requires a firm understanding of the common mechanisms of injury, biologic principles of healing, and the most successful reconstructive techniques. Careful planning for each repair and precise execution of technique ensure the best possible result in even the most devastating of injuries. Patients should be made aware at the initiation of treatment that some injuries will benefit from revision or secondary reconstruction even after appropriate primary surgical correction has been performed.

PEARLS

- Copious irrigation, conservative débridement, a hemostatic field, and careful preparation set the stage for successful wound closure.
- Precise suturing with everted wound edges yields the most predictable healing and the best aesthetic results.
- Planning closure and local flaps to respect the RSTLs optimizes aesthetic healing.
- Discuss revision possibilities at the initial repair by highlighting the likelihood of revision in severe wounds.

PITFALLS

- Do not consider performing very complex closures in the emergency department setting because patient cooperation, optimal lighting, and quality instrumentation will probably improve the outcome.
- Do not perform definitive closure of an extensive gunshot wound at the first visit because most will require additional débridement.
- Inspect areas with complex anatomy carefully because injury to specialized structures is much better managed definitively at the initial repair than at a secondary procedure.
- Postoperative wound care and protection are important to avoid complications and to discuss the expectations of healing or revision.