Chapter 22: Lacerations and Scar Revision

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Lacerations

Wound classifications

The standard first aid text of the American Red Cross classifies wounds as open or closed and defines an open wound as any wound involving a break in the skin or the mucous membrane.

The Red Cross further classifies open wounds into five types: abrasions, incisions, lacerations, punctures, and avulsions. An incision is a clean wound such as a knife makes, whereas a laceration has a jagged edge such as a traumatic shearing injury would cause.

First aid

First aid for open wounds requires stopping the bleeding, protecting the wound from contamination and infection, providing care for shock, and obtaining medical attention. Bleeding is best controlled by direct pressure and can be lessened by elevating the injured tissue. Applying pressure to the supplying artery is useful in some cases; only rarely should a constricting tourniquet be necessary. The wound is kept clean with a dressing, and the patient is treated for shock and transported to an emergency room. At this point a physician begins the medical evaluation and institutes proper medical treatment.

Diagnostic assessment

The medical evaluation always begins with an overall patient assessment to ensure that the patient is breathing, has a beating heart, and is not bleeding severely. The physician looks for other major, more important injuries such as head trauma or a fractured cervical spine. Convinced that no other matter is more pressing, the physician can investigate the wound. No matter how slight the wound, it should be evaluated for injury to bones, nerves, ducts, vessels, muscles, mucosa, and skin. Bony injury is detected by observing hypesthesia, asymmetry or deformity, or change in function such as diplopia or trismus, by palpation, and finally by radiographic evaluation. The primary nervous functions of the face are sensation by the fifth cranial nerve (CN V) and facial movement under the control of the seventh cranial nerve (CN VII). To some degree the astute physician suspects nerve injury. For example, if an infraorbital rim fracture exists, the experienced physician knows that these fractures invariably course through the infraorbital nerve canal, resulting in decreased sensation over that cheek. The facial nerve is at particular risk with penetrating injuries and lacerations in the region of the parotid gland. With injuries of this area, the physician must carefully assess and document the level of function of all branches of the facial nerve.

The two ducts in the head and neck that, if injured, cause dysfunction are the lacrimal duct and the parotid duct. Injury to the submandibular ducts rarely causes dysfunction. Such an injury must be suspected whenever trauma occurs in the vicinity of these ducts, and proper evaluation requires cannulating the respective ducts and determining that they are intact and

functioning.

Although a myriad of small vessels in the head and neck bleed profusely when cut, only injuries to the internal carotid arteries, the vertebral arteries, and the intracranial vessels causes dysfunction. Therefore, if the external carotid artery, the facial artery, or the angular artery has been lacerated, it can simply be ligated. In general, if a vessel is large enough to be specifically named, ligating it with a suture is probably best. Smaller vessels can be controlled by cautery. Detecting muscle injury at the time of wound examination is important. Mucosal and skin injuries are detected simply by examination and palpation.

Management

Management of lacerations begins with wound cleaning. If the wound is a clean laceration such as one made by a knife or broken glass, the wound and surrounding tissues are adequately cleaned with a 2- to 5-minute gentle povidone-iodine (Betadine) scrub. A potentially contaminated wound, such as an older wound or one made by a dirty object, should be scrubbed vigorously and irrigated with povidone-iodine and may on occasion need debridement. Any foreign material in the wound, such as dirt and road particles, must be thoroughly removed. Removal may require scrubbing the skin vigorously with a brush, dermabrading it, or even cutting out bits of dirt and other foreign material with No 11 scalpel blade. Pulsatile irrigation is an excellent tool for cleansing wounds. Eye protection is mandatory to protect fluids from splashing into the physicians' and nurses' eyes. Removal of all foreign material at the time of the initial repair is imperative, for if left it may cause a tattoo that will be very difficult to remove later.

Guidelines and rules exist as to which wounds can be closed and what the timing of such closure should be. Most of these rules are for wounds involving the trunk and extremities and do not apply to the head and neck. The blood supply to the face and neck is so rich that the risk of infection in almost any wound is small. Therefore any wound in the head and neck can be closed primarily unless gross contamination is obvious. Dog bites, human bites, and wounds as old as 24 to 48 hours are all easily closed, and while increased risk of infection exists, that risk is small. If infection does occur, it can usually be recognized and effectively treated before any serious sequelae occur. Wounds closed by secondary or tertiary intention leave unsightly scars that are unacceptable on the face.

The indications for the use of antibiotics are rapidly changing. The majority of clean facial wounds do not require antibiotics. If the wound is a dog bite or a human bite or involves the oral or nasal mucosa, it is best to give the patient an antibiotic for 7 to 10 days. While the temptation to treat patients with antibiotics always exists, this temptation must be resisted unless there are bona fide indications. The consequences of injudicious use of antibiotics affect us all and include increases in the cost of medicine, number of antibiotic-resistant bacteria, and number of patients with allergy to antibiotics.

Anesthesia

Most facial wounds can be closed with the patient under local anesthesia. Lidocaine is a safe and effective anesthetic agent. Lidocaine is a safe and effective anesthetic agent. Doses up to 300 mg are usually safe for the average adult. Concentrations of 0.5% to 1% are

effective. Unfortunately, lidocaine is a vasodilator. In the head and neck this causes substantial wound edge bleeding because of the rich vasculature. Therefore epinephrine is normally added to lidocaine solutions. The most commonly used preparation is 1% lidocaine with 1:100.000 epinephrine. For patients with large wounds or with a sensitivity to epinephrine, 0.5% lidocaine with 1:200.000 epinephrine is equally effective. Using a sharp, small-bore needle to inject the anesthetic is important because this reduces the volume of anesthetic injected and causes the patient less discomfort. Most physicians inject more anesthetic than is necessary. It is best to use a 1-inch 30-gauge siliconized needle in most situations. The pain associated with an injection comes from (1) the insertion of the needle through the skin, (2) the tissue distortion caused by the volume of anesthetic agent used, and (3) a burning sensation caused by the epinephrine. Injecting 0.5% lidocaine with 1:200.000 epinephrine slowly through a 30-gauge needle causes minimal discomfort.

Nerve blocks can be used where possible, but local infiltration is employed for most wounds so as to provide both anesthesia and hemostasis. Lidocaine is effective for only 30 to 60 minutes. If a longer period of time is required, supplemental anesthetic can be given with bupivacaine (Marcaine). Bupivacaine is not ideal as a single agent because its onset is much slower than lidocaine and the anesthesia it provides is sometimes inadequate. The total dose of bupivacaine permissible for an average adult is around 120 mg. A 0.5% concentration should be used, since the 0.25% concentration does not seem to give effective anesthesia. The 0.75% solution is more than is needed and increases the risk of toxicity.

Internal repairs

In most instances hemostasis is readily achieved by direct pressure. Large named vessels such as the facial artery or angular vessels should be ligated with 4-0 chromic, 4-0 Vicryl, or 4-0 silk suture. All other bleeding points are easily controlled with cautery.

Skeletal injuries should be repaired before the soft tissues are repaired. The principles of skeletal repair are discussed in Chapter 23.

Injuries to large motor nerves such as the trunk or major branches of the facial nerve must be repaired. Fortunately, the facial nerve carries only motor fibers, and fascicular repair is unnecessary. Equally good results should be obtained with most gentle nerve suture techniques. Concern exists about the optimal timing of this repair. Although some studies have suggested that waiting 3 weeks may be preferable in cats, this benefit has not been substantiated in humans, nor is the delay practical. The common practice is to repair nerves at the time of initial treatment. The surgeon should repair motor nerves under a microscope, using several epineural stitches (Fig. 22-1). If the surgeon is skilled in microscopic anastomosis, 10-0 monofilament nylon is recommended. However, if the proper instruments are not available or the surgeon is not practiced in microanastomotic surgery, using 8-0 monofilament nylon is best. For large nerves such as the trunk of the facial nerve, four or five individual epineural sutures are required; for smaller nerve branches, two stitches may be sufficient. Wrapping the anastomosis with silicone is of little value.

Wounds of the lacrimal system, the parotid duct, or the submandibular duct should be repaired. The repair is made by cannulating the duct with an appropriate-sized silicone cannula and then repairing the injured duct over the cannula. If a portion of the duct is

missing, the cannula should be left in place for 6 weeks, and often the endothelium will bridge the gap. If the lacrimal system is totally avulsed and destroyed, a dacryocystorhinostomy will be necessary. This is best done 3 to 6 weeks after the initial injury. If the parotid or submandibular duct is not easily repaired and can be easily marsupialized into the oral cavity, this repair functions as well as a primary one.

Repair of lost or damaged tissue

If extensive tissue damage or loss occurs, several important factors must be considered. Skin that has been abraded will heal with an abnormal texture and color. The degree of deformity is proportional to the depth of abrasion. If this represents a small amount of tissue that can easily be excised, doing so is best. If it represents a substantial area of skin, letting this heal and then performing a scar revision at a later date is preferred. Jagged wound edges should not be trimmed, and the surgeon should do the best possible job of reapproximating the respective jagged edges. This often gives a superior result as will be evidenced in later sections dealing with running W-plasties and geometric broken-line closures. However, if some of the irregular edges contain devitalized tissue, it is best trimmed at the time of the primary repair. A defect resulting from tissue loss, as is seen in an avulsion wound, must be closed. If the loss is small, the wound can be closed by undermining and advancing local tissue. If the defect is larger, using a local skin flap may be necessary. In even larger wounds, more involved techniques such as skin grafts or regional flaps may be necessary. If in doubt, the surgeon should cover the wound with a skin graft and perform a revision later when all the different reconstructive methods can be considered.

If supporting tissue such as cartilage from the nose or ear has been lost, autogenous or homologous cartilage may be used for the reconstruction. For very small cartilaginous defects, cartilage can be taken from the patient's nasal septum or ear, or on rare occasions costal cartilage can be used. If the avulsed tissue is brought to the emergency room with the patient and can be cleaned, it can be put back in place in an effort to have it accepted as a free graft. Small segments of skin heal easily, but larger tissue grafts heal with difficulty. If vessels are available for microvascular anastomosis, the chance of tissue survival will certainly improve.

Three theories of repairing an avulsed ear exist. The first is simply to sew the ear back in place in the hope that it will take. When this is done, multiple cutaneous incisions should be made on both surfaces of the ear to allow drainage of serous exudate. In addition, if a hyperbaric oxygen chamber is available, hyperbaric oxygen treatments for a week or two will improve the chance of survival. Without hyperbaric oxygenation the success rate for this method is poor, and many surgeons prefer taking the skin off the cartilage and banking the cartilage underneath the skin of the abdomen until reconstruction can be performed. I have had success and failure with both of these techniques. Recently, sporadic success has been reported with microvascular anastomosis. If microvascular expertise is available, the avulsed tissue is maintained in iced saline and the microvascular team performs the repair in the operating room. Microvascular repair probably has the highest success rate and should be considered whenever available.

If a portion of the nose or ear is avulsed, the segment should simply be sutured in place and treated as a composite graft. If a piece of soft tissue has been avulsed from the

cheek or lip as in a bite injury, that tissue should not be replaced because it will have neither sensory nor motor innervation, and most such defects can be closed by rearranging local tissues.

Occasionally the physician sees an injury in which the entire scalp is avulsed. This occurs most commonly in a person whose long hair is caught in a rapidly revolving wheel and whose scalp is literally jerked from the head. Simply suturing the scalp back in place is doomed to failure. Fortunately, the scalp is supplied by four major vessels, and if any of these can be reanastomosed by microvascular surgical technique, the scalp has a good chance of surviving. Therefore, if a patient has a scalping injury the best treatment plan is to ask a surgeon who performs microvascular anastomoses to repair the scalp.

The vessels of the head and neck, other than the common and internal carotid arteries, do not need to be repaired.

Muscle and tendon repair

If the patient is to regain normal facial function, all muscles should be reunited. In areas such as the corner of the mouth where numerous small muscles pull in different directions, realigning them precisely is particularly important. However, in the neck and most areas of the face such as the forehead and cheek, general realignment is adequate. When muscle bundles are being repaired, 4-0 Vicryl or Dexon is effective. However, if a fascial system exists with the muscle, a permanent suture such as 4-0 nylon to approximate the fascia is preferred. Because how muscles are sutured does not seem to matter, at least on the face, a single stitch is employed, passing the needle through the fascia on one side, through the muscle, and out the fascia on the other side. The suture must be placed identically through muscle and fascia on both sides. Several sutures should be used for each muscle in case a suture pulls loose. In complex areas such as the corner of the mouth, the lips, and about the eyes, failure to reapproximate the muscles will cause a significant deformity.

The most important tendons in the face are those of the medial and lateral canthi. These must be repaired with a permanent suture such as 4-0 nylon.

Mucosal lacerations are closed with absorbable sutures. Chromic catgut, Vicryl, and Dexon seem to be equally effective. For large lacerations, interrupted vertical mattress sutures give the safest closure. For small lacerations and when a watertight closure is needed, a simple running or running locking stitch does well. If a large potential dead space exists, it should be obliterated with interrupted absorbable suture.

Skin closure

The principles of skin closure are simple, although the practice is never perfected. Deep stitches approximate the dermis. The purpose of these stitches is to take the tension off the wound edge and to align the skin for the surface closure. This step is followed by any of several techniques for closing the skin. The goal is to align the epidermis carefully so as to provide the best opportunity for an aesthetically acceptable scar. The standard training today for the deep sutures is to use a 4-0 Vicryl or Dexon suture that is passed through dermis and subcutaneous tissue as in Fig. 22-2. A number of these are placed along the wound edge;

some surgeons believe that the more stitches are placed, the better the result. In my opinion, when each one of these is pulled tight, the local blood flow is strangulated and wound healing is adversely affected. Therefore the fewer sutures used to achieve approximation, the better. In addition, if these sutures are placed too near the surface, they may not provide the best opportunity to create an everted wound. For these reasons, I prefer to place the subcutaneous dermal stitches approximately 1 cm from the wound edge (Fig. 22-3). By so doing, far fewer stitches are needed, the blood supply to the wound edge is less compromised, and the wound edges are easily everted with the superficial stitches.

Using an absorbable suture is important because a permanent material such as nylon, silk, or cotton can be extruded from the skin as a foreign body. Surgeons who place 20 to 50 of these in a patient may be required to see the patient 20 to 50 times postoperatively to remove each extruding stitch. Plain and chromic catgut are not ideal in the face because they may be absorbed too quickly. Polyglycolic acid sutures maintain good strength for 3 months and cause minimal inflammation. They are eventually absorbed completely and are now preferred by most head and neck surgeons.

Skin closure techniques. Many different techniques may be used for the superficial cutaneous closure, and it is doubtful that a single best technique for all physicians will ever exist.

Fig. 22-4 illustrates the five most frequently used stitches, and a description follows. A certain amount of eversion is desirable, and for this purpose interrupted *vertical mattress sutures* are optimal. Unfortunately, placing a vertical mattress suture takes twice as long as most other methods, and so these sutures are not always practical. Tissue trauma is an important factor in the ultimate result. Whether the surgeon uses skin hooks or fine forceps is irrelevant, but how these instruments are used is very relevant. The tissue must be handled as gently and infrequently as possible. When the sutures are removed, the tissue suffers additional trauma, and the patient may experience some additional discomfort.

Another excellent stitch but certainly a more difficult one to place is the *running subcuticular suture.* For surgeons who frequently perform meticulous wound repairs, this technique gives excellent results once it is perfected.

Because interrupted sutures take longer to place and may cause unneeded tissue trauma and suture marks, many surgeons prefer to use *running stitches.* The *simple running stitch* is the most commonly used, with the *running locking stitch* also used frequently. The latter usually allows a more precise alignment of skin, but unfortunately, if pulled too tight, it can jeopardize blood supply to the wound edge. A technique I use for most wounds, particularly those in children, in whom suture removal is difficult, is a running lock stitch of 6-0 fast-acting chromic catgut. This suture material is rapidly absorbed and is gone in 3 to 5 days. The added inflammation caused by the catgut does not seem to adversely affect wound healing. I have never seen suture marks left by this material, even if strands of suture persist for 1 or 2 weeks. Because the suture may dissolve in some areas in as little as 2 to 3 days, the running lock suture is preferred so the entire stitch does not come loose.

Whatever technique is chosen, it should be performed with small superficial bites that approximate the wound margins without tension. The stitch should include 25% to 50% of

the thickness of the skin except where the skin is very thin. In these locations the suture should include the full skin thickness. Sutures should not be pulled too tight because they could strangulate tissue and cause suture marks.

Drains and dressings. If the wound is large with much oozing or if the potential for infection is high, a small drain can be left in the wound. Generally a small Penrose or even a rubberband drain will suffice.

All wounds should be dressed. Normally an occlusive dressing is applied, since this improves epidermal healing and therefore the final appearance. The wound can be covered with a nonadherent dressing such as a Telfa pad or with Steri-Strips. The second layer of the dressing should contain absorbent material such as gauze. The third layer should place gentle pressure on the wound and may be applied in such a way that it decreases tension across the wound. Properly applied Steri-Strips do this on the first dressing layer, but if a Telfa-paper tape dressing is used, the antitension effect is achieved with the paper tape layer. The second and third layers of the dressing are changed after 24 hours, and all three layers are removed after 3 or 4 days. The sutures are removed on the third or the fourth postoperative day. If they are not removed until the fifth postoperative day or later, the risk of epithelial growth down the suture increases, resulting in a permanent suture mark. If 6-0 fast-acting gut sutures are used, Steri-Strips are imperative because they enhance the suture breakdown. The Steri-Strips are removed after 3 or 4 days and then are reapplied for an additional 3 to 5 days. If some suture material persists after 6 to 7 days, it can be gently cut and pulled free.

All wounds should be observed by a physician, initially to be sure they do not become infected and then to be sure they do not form hypertrophic scar. If hypertrophic scar or keloid is formed, the earlier it is recognized, the better the outcome.

Problems. Four potential problems are associated with traumatic wounds: (1) wound infection, (2) hypertrophic scar and keloid formation, (3) aesthetically unacceptable scar, and (4) psychologic nonacceptance. Wound infection is more common with dirty wounds, particularly animal or human bites, and infection becomes more likely the greater the time between wounding and wound closure. In addition, infection is more likely in a patient with impaired resistance or poor blood supply to the tissues such as in a diabetic or a patient with multiple injuries who is hypertensive, hypoxic, and so on. Generally a wound infection becomes apparent 24 to 72 hours after wound closure and appears as a reddened, painful swelling. Cellulitis, a superficial spreading infection most commonly caused by *Streptococcus,* is treated with penicillin. An abscess is most commonly caused by *Staphylococcus.* If the wound has been exposed to oral cavity anaerobes, a mixed anaerobic abscess may form. When an abscess occurs, the wound must be opened sufficiently to drain all of the exudate. A sample should be sent for culture and sensitivity testing. The wound should be irrigated with povidone-iodine solution and drained. If the bacterial agent is most likely staphylococcal, dicloxacillin should be administered. If it is uncertain which bacterium is causing the infection, a Gram stain should be taken. If gram-positive cocci are present in clumps, the patient can be given dicloxacillin; if other bacteria, particularly those associated with anaerobic infections, are present, the patient should be given penicillin or other appropriate antibiotics. The antibiotic regimen is then adjusted when the culture and sensitivity results are available. The wound should be examined and irrigated daily, and the drain changed or examined for patency. When the wound is clearly healing and the drainage has subsided

(normally within 3 days after incision and drainage), the drain can be removed. However, the antibiotics should be continued for at least 10 days.

Hypertrophic scar and keloid formation is the result of overzealous wound healing. Some physicians believe that hypertrophic scar and keloid are different entities, whereas others view them as points on a continuum. Both hypertrophic scar and keloid appear initially as red, inflamed excessive scar tissue commonly associated with itching. As soon as this begins (as early as 4 weeks after the wound repair or as late as a year or two after repair), the abnormal scar should be injected with a long-acting steroid preparation. Triamcinolone (Kenalog-40) is the most commonly used steroid. It can be injected into the wound with a Dermajet or with a needle and syringe. If a needle and syringe are used, a 25- or 27-gauge needle is necessary. The triamcinolone should be injected into the scar and not the normal tissue surrounding the scar. The preferred concentration is 40 mg/mL, and if delivered through a Dermajet, 0.1 mL can be deposited every 5 to 10 mm along the wound. This is repeated at 2- to 3-week intervals until the hypertrophic scar or keloid disappears.

Hypertrophic scar usually disappears after one or at the most three applications of steroids. Keloids can be more resistant and may require multiple applications. For difficult keloids, the Dermajet does not deliver sufficient volumes of triamcinolone. After the wound has been softened with two or three doses of triamcinolone delivered through the Dermajet, subsequent injections should be given into the keloid with a 27-gauge needle. Only very large keloids require excision or irradiation. Most keloids can be treated successfully with multiple injections of triamcinolone. If the keloid large and mature, as many as 20 or 30 injections may be necessary. A keloid detected and treated early would be unlikely to require more than 10 injections. The maximum acceptable dosage of triamcinolone per month is 120 mg for adults, 80 mg for children 6 to 10 years of age, and 40 mg for children 1 to 5 years.

The third problem sometimes associated with a facial wound is an aesthetically unacceptable scar. All wounds leave some scar tissue, and every patient must recognize that even with revision a scar will remain. All scars improve with time and with scar maturation. Coaching the patient to wait and see how the scar develops is important. The scar that may look unacceptable at 6 weeks or even 6 months may mature and be perfectly acceptable after 1 or 2 years. This is dealt with further in the section on scar revision.

The fourth problem is the psychologic damage that can occur from a traumatic wound of the face. Since no one wants to be injured or deformed, some psychologic trauma is related to every wound. Wounds resulting from one's own follies seem to be less stressful than those inflicted by someone else. For example, an inebriated person who falls and cut himself on the kitchen table has no one to blame but himself and tends to be psychologically more accepting of the wound. In contrast, a person who suffers a facial laceration while sitting in a parked car that is hit by another car, whose driver is inebriated and has a history of multiple arrests for drunk driving, will be angry and difficult to deal with psychologically. Similarities exist between the psychologic response to death and dying and the response to traumatic wounding. The elements of grief, anger, denial, bargaining, and ultimate acceptance are common to both. The surgeon should never perform a scar revision on a patient who is still angry and refuses to accept the fact that he has a deforming scar. The angry patient will never be pleased until the blemish is entirely removed from his face, an impossible goal to achieve. No matter how skilled the scar revision, the patient will be unhappy and will turn his anger toward his

physician. Once a patient accepts the scar, he will be grateful for any improvement and at that time is a good candidate psychologically for scar revision. Sometimes getting a psychiatric evaluation is necessary before doing a scar revision. Finally, as a general rule, a patient involved in litigation relating to his scar will not be a good candidate until the litigation is resolved. It is amazing how many patients who show great anger over a scar completely forget about the scar and its deformity when the lawsuit is settled.

Scar Revision

Any scar that is longer than 2 cm, wider than 2 mm, distorts normal anatomy, or does not lie in a favorable skin tension line may be improved by scar revision.

Scar revision carries four requirements: (1) that the patient desires having the scar revised, (2) that the patient is in a state of mind allowing him to benefit from scar revision, (3) that the scar is mature, and (4) that revision can reasonably be expected to improve the appearance of the scar.

The question of timing is an important one. First, the patient must be psychologically prepared. That is, he is no longer angry about having a scar and will be satisfied with a degree of improvement. The patient cannot expect the ultimate result to be perfect. Second, the scar should be mature, since whether or not a scar needs revision may not be known until it has had the opportunity to mature. The healing of the initial wound gives the surgeon valuable information as to what to expect with the healing of the scar revision. Waiting for scar maturation forces the patient to become comfortable with the scar and psychologically prepared to benefit from scar revision. Generally the waiting period is 1 year. It should rarely be less than 6 months, even if the tissues are physiologically ready, since the patient will probably not be psychologically prepared.

Correcting underlying deformities

Before beginning scar revision, the surgeon must correct all underlying deformities. For example, reconstruction of the lacrimal system or of the medial canthal tendon or correction of a skeletal deformity may be necessary before the scar revision.

Sites for incision

Before beginning scar revision, the surgeon must understand the most favorable sites for incision. These are (1) inside an orifice such as the nose, mouth, or ear, (2) in a place that may be covered by hair, (3) at the junction of two aesthetic areas, and (4) in or paralleling favorable skin tension lines. While the first two may be useful in designing elective surgery, they are rarely useful in scar revision unless the surgeon can move a scar from an unfavorable site into an orifice or the hairline. Sometimes a scar can be moved into the junction of two aesthetic areas. These include the junction of the forehead with the nose, the forehead with the temple, the temple with the cheek, the temple and the cheek with the eyelid, the cheek with the nose, the cheek with the lip, the cheek with the chin, and the chin with the lip. An incision placed exactly in the boundary or junction of two areas generally forms a less obvious scar than one placed even a millimeter or two away from that boundary.

The lines that naturally occur on a person's face as a result of gravity, aging, and facial expression have been given a number of names, and to date no name is universally accepted. As early as the 1800s, these lines were of interest to surgeons, and Langer described a series of them. Other surgeons have described similarly oriented lines in relation to underlying musculature and have suggested a variety of names such as "relaxed skin tension lines". I call them favorable skin tension lines. In an older patient on whom these lines have already formed as wrinkles, crow's-feet, and smile lines, identifying the favorable skin tension lines is easy. However, in a young patient guessing where the favorable skin tension lines lie and where wrinkles will lie later in life may be difficult. The easiest way to do this is to ask the patient to go through a number of facial movements such as smiling, frowning, and wrinkling the nose. The skin creases that form indicate the favorable skin tension lines. Even a young child when asked to squinch his nose will wrinkle the skin along the favorable tension lines. The orientation of these lines is similar from one patient to another but is also unique in each patient. The precise positions of the lines are extremely important because they dictate the preferred geometry for each scar revision.

Techniques

Simple excision

Simple excision is the least complicated scar revision technique but is rarely the technique of choice. If the scar parallels a favorable skin tension line or lies within a wrinkle or at the junction of two aesthetic areas, but for some reason did not heal well initially, it is common to expect that simple reexcision and approximation will result in a better scar. Often incisions have been closed primarily in an emergency room. The surgeon performing the scar revision may think that he can excise the scar and close the wound under more favorable conditions, perhaps with more meticulous suture technique, and obtain a better result. All too often this plan fails. Thus, simple excision should be reserved for scars that have initially healed with a complication that has caused a less favorable appearance and that lie within a hairline or at the junction of two aesthetic areas. In addition, it may be an adequate technique for some scars that parallel favorable skin tension lines and are shorter than 2 cm.

Simple excision is easy to perform. The surgeon merely excises the scar, undermines the wound edges for about 1 cm, and closes the wound as described later in the section dealing with wound repair. It is important to take all tension off the wound closure to avoid tissue injury and to evert the wound edges. If the initial scar was depressed, the surgeon may remove the epithelium from the scar, leaving the dermal scar tissue in place. The edges of the wound are the advanced over this dermal scar, which acts as filler.

Serial excision

Removal of a large scar resulting from excision of a large hairy nevus, an area of tissue loss that has been closed with a skin graft, or a burn injury can be accomplished by serially excising it in several operations. The technique of serial excision involves making an incision at one side of the scar, undermining the wound edges, excising the scarred area or a portion of it, and closing the wound edges under moderate tension. Over the next 6 to 12 weeks the skin stretches. The surgeon can then repeat the procedure again and again until the unwanted scar has been excised. Skin has a tremendous potential to stretch as long as it is

pulled slowly in this fashion, and even large defects such as those covering 30% to 40% of the forehead can be closed by serial excision. All initial incisions and closures must be made within the scar tissue to avoid sacrificing nonscarred, healthy tissue. In the last operation the remaining bit of scar tissue is excised and normal, healthy tissue is approximated to normal, healthy tissue on the opposing side. This last procedure is sometimes done in a straight line but more often is done as a broken-line closure as discussed later in this chapter. In addition to excising large scarred areas, serial excision is used to move a scar into a hairline, into the junction of two aesthetic areas, or to a less visible site.

An alternative to serial excision is tissue expansion. This is described well in the literature. Conceptually, the existing skin is expanded over time to cover the tissue deficiency. For certain thicker-skinned areas with a rigid underlying skeleton such as the forehead and scalp, this appears to be a useful technique. Other areas such as the eyelid and cheek are not as well served.

Z-plasty

Z-plasty is another important and useful technique in scar revision. A Z-plasty accomplishes two things: lengthening the scar and changing its direction. It does so, however, at a significant price. To whatever degree it lengthens in one direction, it shortens the tissue in the perpendicular direction, and if this tissue is already tight or is vascularly compromised, additional stretching can be dangerous. Furthermore, a Z-plasty requires two extra incisions, so rather than one scar, albeit less than perfect, three scars will now exist.

The most useful application for a Z-plasty is to correct a linear incision that crosses the junction of two aesthetic areas where the natural tissues are concave and therefore the contracted scar is causing a web that crosses the junction or an important favorable skin tension line.

Designing and transposing the triangular flaps of a Z-plasty can be difficult. A Z-plasty is simply two flaps that are transposed one over the other in such a way that tissue is borrowed from areas of excess and transposed into areas of deficiency. At the same time, the orientation of the revised scar is rotated about 90 degrees (Fig. 22-5). Assuming that a scar exists (indicated by the line 1-2 in Fig. 22-5), has contracted, and lies in an unfavorable direction, the goal would be to lengthen the scar and change its orientation to a more favorable one. This is begun by excising the scar (1-2) to form the central limb. Two triangular flaps are now created by making two parallel incision, one beginning at 1 and the other beginning at 2. These incisions are called the lateral limbs. The angles between the central limb and the lateral limbs must be equal at 1 and 2. This angle is used to define the Z-plasty: that is, if the angle is 60 degrees, the Z-plasty is called a 60-degree Z-plasty. The triangular flaps and the surrounding tissues are undermined and the flaps are transposed, one over and one under. In so doing, the original scar length is lengthened and the orientation of the central limb is changed. The amount of lengthening achieved is a function of the length of the central and lateral limbs and of the angle of the Z-plasty. The greater the angle, the greater the lengthening. Fig. 22-6 indicates the theoretic degree of lengthening achieved with classic 30-, 45-, and 60-degree Z-plasties. Surgeons most commonly employ 60-degree angles because they provide a reasonable balance between lengthening and local tissue distortion. Theoretically the surgeon could use 120- or 150-degree Z-plasties and achieve a high degree

of lengthening, but the cost would be tremendous local tissue distortion and protrusion.

In designing a Z-plasty as shown in Fig. 22-7, the surgeon must pay attention to the orientation of the lateral limbs. Every Z-plasty has four different possible designs for the lateral limbs. Only one design is optimal. In most Z-plasties the central limb lies perpendicular to the favorable skin tension lines. In one orientation the lateral limbs parallel the favorable skin tension lines, and in another orientation the lateral limbs lie across favorable skin tension lines. The correctly designed Z-plasty employs lateral limbs that parallel favorable skin tension lines. This is so important that, if the favorable skin tension lines in a given area are not parallel, the surgeon would even use different angles for the two transposing flaps to keep the lateral limbs in and parallel to favorable skin tension lines. It is also important that the ends of the lateral limbs lie precisely in the line where the new central limb will be placed. Fig. 22-8 shows two Z-plasties. The dotted lines joining the ends of the lateral limb lie where the new central limb will lie. The second Z-plasty employs different angle transposition flaps. This trick is often used to ensure that the lateral limbs parallel favorable skin tension lines and that the new central limb lies precisely where desired.

Compound Z-plasty

Compound Z-plasty (Fig. 22-9, A) may be necessary to lengthen a long linear scar in situations where doing this as a single Z-plasty is disadvantageous. A large single Z-plasty is undesirable if it would necessitate incising and transposing very large flaps. The wide angles used cause undesirable tissue protrusions. One alternative is to incise and transpose a series of smaller flaps. This procedure, called serial Z-plasty, is diagrammed in Fig. 22-9, B. An alternative to serial Z-plasty is multiple Z-plasty as depicted in Fig. 22-9, C. Multiple Z-plasty may cause unnecessary tissue protrusions if not done properly. Therefore, before performing these techniques on a patient, the surgeon is strongly encouraged to draw the designs and closures of many different types of Z-plasty on a piece of pliant rubber. Alternatively, the surgeon can take squares of elastoplast and stick them back to back in such a way that they are rotated 90 degrees before pasting them back to back. This creates a field that is uniformly elastic in most directions, making an excellent model for practicing Z-plasty and local skin flaps.

Broken-line closure

The techniques discussed so far provide the surgeon with a limited ability to improve the majority of facial scars. Not until the concepts of running W-plasty and geometric broken-line closure were developed could the surgeon make real improvements in most facial scars.

The concept of a broken line is simple. The eye easily perceives a straight line, it easily follows that line. For this reason a linear scar, no matter how carefully created, is never truly inconspicuous. The broken-line techniques of scar revision address this problem. By creating a scar that is a series of short, broken lines, the surgeon can fool the eye. The first attempts at broken-line closures used serial Z-plasties, but these sometimes were disadvantageous because of the lengthening created by Z-plasties. The next pattern used was the running W-plasty, and the last pattern developed is called a *geometric broken line*. Fig. 22-10 compares simple excision, Z-plasty, running W-plasty, and a geometric broken line.

The *running W-plasty* is a useful and simple scar revision technique. The scar is excised with a minimal amount of normal tissue, using the design shown in Fig. 22-11. The two wound edges are undermined and advanced together, and the small triangular flaps and defects are interdigitated as shown. When properly done, this technique creates a less conspicuous scar. To be effective, each straight line must be no longer than 5 mm and each of the angles connecting the straight-line segments must be 90 degrees or less. The human eye perceives one of the short segments and follows it. When it comes to the end of the segment, the eye sees normal tissue. The eye returns, picks up the next segment, and follows it. Because the angles are acute, the eye does not readily follow from one broken segment to the next. Thus a broken-line scar is less noticeable than is a straight or curvilinear scar.

Fig. 22-12 shows how a running W-plasty can be adapted to a curvilinear scar, and Fig. 22-13 shows how the orientation of the triangular flaps is tailored to the orientation of surrounding favorable skin tension lines.

Occasionally the end of a scar is very wide so that bringing the end to a 30-degree angle to prevent protrusion may create a longer linear scar and may necessitate excising excessive normal tissue. Using an *M-plasty* (Fig. 22-14) saves tissue, decreases the length of linear scar, and prevents tissue protrusion as effectively as a single 30-degree angle. Advancing or retarding the tip of the M-plasty during wound closure further controls the orientation and length of the final scar (Fig. 22-15).

Fig. 22-16 shows a typical scar revision. An M-plasty is used at the left end of the scar. A running W-plasty adapts well to the curved portion of the scar, and a 60-degree transposition flap is used at the wide end of the scar. This fits nicely into the pattern of the running W-plasty.

Unfortunately, with longer scar revision a running W-plasty develops a pattern that can be recognized, and for this reason the *geometric broken line* was developed as an improvement. Fig. 22-17 depicts a geometric broken-line design excision and closure. The only difference is that each flap is of a slightly different size and shape than those around it so the ultimate pattern is completely unpredictable. When properly done the geometric broken line is a superior technique for scar revision.

Refining technique

Several tricks will improve the surgeon's ability to use scar revision techniques. A running W-plasty and a geometric broken line must be properly designed. As many of the short segments as possible should lie parallel to favorable skin tension lines, and as few as possible should lie perpendicular to favorable skin tension lines. As with the running W-plasty (see Fig. 22-13), the design of a geometric broken line is tailored to fit the favorable skin tension lines. Because the flaps on either side of the wound must be interdigitated, the height of the flaps and respective defects must be the same. Beginning at either end of the scar, the surgeon creates very short flaps, with the first flap 2 mm, the next flap 3 mm, the next 4 mm, and the rest between 4 and 5 mm (Fig. 22. 18). The width of the various flaps should vary. The difficulty, of course, is to make each flap and its recipient site similar in all aspects. By drawing a series of lines perpendicular to the scar, the surgeon defines the limits for each flap and recipient site. Then respective flaps and recipient sites for each box are simply filled in.

This is particularly useful when the scar goes around a curve, since the design on the concave side is significantly smaller than the design on the convex side. Although designing square, trapezoid, and rectangular flaps and defects around a curve is possible, using triangular flaps for these areas is easiest. Whenever a scar goes around a curve, across a concavity, or over a convexity, triangular flaps are best.

If lengthening is required in the scar revision, interrupting the geometric broken line or the running W-plasty and putting in one or several Z-plasties is easy. Creating length with a running W-plasty by designing a series of Y to V maneuvers is also easy (Fig. 22-19). This design is particularly useful for tracheal scar revision. The disadvantage of using the Y to V maneuvers is that the flaps ultimately become 7 to 10 mm in length and are therefore more conspicuous than shorter flaps.

Closing a broken-line excision should be simple. The wound edges on either side are undermined for a distance of 1 to 2 cm, and the wound edges are brought together with interrupted absorbable sutures placed at least 5 mm back from each wound edge. This preserves blood supply to the flaps, relieves the tension from the wound edges, and allows the wound edges to be closed with eversion. To close a geometric broken line or even a running W-plasty with interrupted, monofilament permanent suture would be too time consuming. A preferred and much quicker technique is to use 6-0 fast-acting gut suture in a running, locking stitch, catching all of the flap corners on one side of a wound, crossing over to the other side of the wound, catching all of the flap corners on the second side of the wound, and ultimately tying the suture to itself (Fig. 22-20).

The inexperienced surgeon may have difficulty cutting small angulated flaps. They can be most easily incised with a No 11 blade held vertically (Fig. 22-21). On delicate skin such as the upper lip or the eyelid, using flaps that are only 2 to 3 mm in length will be necessary, whereas in larger, less delicate surface such as the cheek and the forehead, larger flaps (5 to 6 mm) are permissible. After the wound is sutured, it is immobilized by criss-crossing it with Steri-Strips to prevent tension on the closure for at least 3 months. If the subcutaneous intradermal sutures are properly placed, they will carry most of the tension. The scar is then allowed to heal and mature. Six to 12 months later, when the scar is fully mature, it can be further improved with dermabrasion.

The scar is visible because, when the scar edge is sharply vertical, it creates a shadow. In poorly or brightly lit environments, scars are generally less visible. By saucerizing the scar with dermabrasion, the edges are smoothed and no shadow is created. In addition, most scar tissue has a slightly glassy appearance. The dermabrasion removes the epidermis of the scar and the adjacent skin as well. When the epidermis regrows, it more nearly matches that of the surrounding normal tissue.

Case Studies

The first patient is a 26-year-old woman who was involved in an automobile accident and when first evaluated had the appearance shown in Fig. 22-22, A. The injuries included bony fractures of the right malar bone and orbital floor. The eye was enophthalmic and was inferiorly displaced into the maxillary sinus. The cheek bone was depressed. All of the soft tissues of the right medial canthus had been avulsed, and the medical canthal ligament and

lacrimal system were disrupted. The laceration at the corner of the mouth involved skin, muscle, and some mucous membrane. The laceration beneath the lower lip extended through the mucosa into the mouth. The skin was abraded and contained a moderate amount of road dirt.

After the patient was stabilized and other, more serious injuries were excluded, she was brought to the operating room. Under general endotracheal anesthesia the wounds were cleaned and all the dirt was meticulously scrubbed from her face. The medial canthal ligament was identified and sutured to the periosteum of the nasal bone with a 4-0 nylon suture. The malar and orbital floor fractures were explored, reduced, and wired in position. The orbital floor was reconstructed with a piece of Silastic sheeting. All the mucosal wounds were closed with 4-0 Vicryl, and all the muscles were reapproximated with 4-0 Vicryl. The skin was closed with 4-0 Vicryl placed in the subcutaneous tissue and with 6-0 fast-acting gut for the superficial sutures.

The patient healed well but had a persistent epiphora. A dacryocystorhinostomy using a Lester Jones glass tube was performed, Fig. 22-22, B, shows the patient approximately 3 months after the initial repair, and Fig. 22-22, C, shows the patient the same day after professional cosmetic consultation. Further scar revisions are planned but will not be performed until all the scar tissue has had an opportunity to mature.

The patient shown in Fig. 22-23 is a 19-year-old woman who was involved in an automobile accident in Mexico. She did not receive medical care until approximately 10 days after the injury. Fig. 22-23, A, shows the patient at the time of initial examination. She was given a general anesthetic, and the wounds were meticulously scrubbed. Unfortunately, removing of all of the road dirt from her face was impossible. In addition, there was substantial tissue loss, most evident around the right lateral canthus. The wounds were closed as well as possible, and the patient is shown in Fig. 22-23, B, shortly after this surgery. Fig. 22-23, C, shows her approximately 3 months after the accident. Some hypertrophic scar, some obvious pigmentation, and some obvious scar and deformity were present. While she waited for the scar tissue to mature, a professional cosmetic consultation was obtained. Fig. 22-23, D, shows the improvement resulting from this consultation.

Several scar revisions were carried out; Fig. 22-23, E to H, shows some of these. Her appearance several years later, a year after the last of multiple surgical procedures, is shown in Fig. 22-23, I to K. She was this time a college student and refused to wear makeup but fortunately had undergone scar revision and had a very acceptable appearance.

The young man shown in Fig. 22-24 was involved in a motorcycle accident in which his nose was essentially avulsed from his face. The bones and cartilages of the nose were severely traumatized. All this material was packed into some sort of anatomic realignment, and all the incisions inside and outside the nose were closed. Fig. 22-24, B and C, shows the result of this injury and repair 1 year later. The major deformity was the loss of support for the nose. This was repaired with a rhinoplasty (Fig. 22-24, D and E). Tip projection was augmented and reinforced with a septal cartilage strut placed in the columella. The dorsum of the nose was augmented with Supramid mesh graft, and the tip of the nose was better defined with a cartilage graft as described in Sheen (1978). Fig. 22-24, F and G, shows the patient's appearance 1 year after the rhinoplasty.

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The principles of wound repair and scar revision are simple. The practice requires a full knowledge of the basic principles, a creative surgeon, a psychologically receptive patient, *patience,* and a little bit of luck.