TITLE: Techniques for Scar Revision
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Introduction

Scarring is an inevitable outcome of any wound that violates the dermis. This may be due to soft-tissue trauma, or it may be an iatrogenic injury. Knowledge of the anatomy of the skin, principles of wound healing, and scar revision principles can improve unsightly or functionally significant scars. Any surgeon who operates on the face should be familiar with methods of designing incisions to minimize aesthetic deformity.

Anatomy and Physiology of the Skin

The skin is divided into three layers –epidermis, dermis, and superficial fascia. The epidermis has five layers. The bottom layer is the basal cell layer or *stratum germinativum* composed of a single layer of cuboidal cells and rest on the basement membrane. Between the basal cells are melanocytes or pigment producing cells. For every 10 basal cells there are one or two melanocytes. The next cell layer is the prickle cell layer or *stratum spinosum*, which is usually three to four cells thick. The next layer above the prickle cell layer is the granular cell layer or *stratum granulosum* which is one to four cells thick. The next layer is the cornified layer, the *stratum corneum*. This is the outermost part of the epidermis and is formed from extremely flattened, anucleated keratinocytes and compacted keratin granules. The palms and soles have a fifth layer of epidermis, the *stratum lucidum*. The epidermis is the protective, waterproof layer. The basal layer continually replicates, pushing dying keratin to the surface. Because the basal layers remain intact in abrasions and burns, healing generally occurs without scarring. However since melanocytes are present in the epidermis, these injuries may result in discoloration.

At the dermal-epidermal junction, the contour of the bottom of the epidermis is irregular with numerous projections known as rete pegs. These projections help to anchor the epidermis to the dermis. Also known as rete ridges, the rete pegs interdigitate with upward elevations of the dermis called dermal papillae. In scars the rete pegs are lost and this lack of rete pegs is one reason why scar epidermis may shear off more easily than with normal epidermis.

The dermis is divided into two parts – the papillary dermis and the reticular dermis. The papillary dermis is relatively thin, located just below the epidermal-dermal junction, and is composed of loose collagen, blood vessels, and fibrocytes. The reticular dermis is relatively thick, located just below the papillary dermis and is composed of compact collagen and fibrocytes. Cutting across the dermis are peripheral branches of the vascular and nervous systems and epidermal appendages (pilosebaceous, apocrine, and eccrine units). Sebaceous glands are the epidermal-lined structures that are the principal source of epithelial regeneration in dermal injuries.

The superficial fascia is below the dermis and above the underlying muscle and is composed of fat cells and a fibrous septae. The thickness of this layer varies from regions of the body, gender, and from individual to individual, and reflects the nutritional status of individuals. It contains the deep plexus of blood vessels to the skin.

Wound Healing

Phases

The stages of wound healing can be temporally organized. The *vascular phase* occurs immediately after wounding and involves 1) early vasoconstriction lasting 5 to 10 minutes and caused by platelet aggregation and fibrin and later 2) vasodilatation with the release of numerous cellular and noncellular blood products into the wound. The *inflammatory phase* is important for the phagocytosis and debridement of foreign material and the killing of bacteria. In addition, these inflammatory events generate a host of soluble mediators important in the migration of fibroblasts into the wound, and the subsequent production of new collagen. This occurs over days to hours.

This leads into the second phase of healing, which is the proliferative phase. Epithelial cells cover the wound, and fibroblasts lay down such products as proteoglycans, elastin, and collagen. Angiogenesis occurs, increasing the access of the body to the wound. This entire process occurs over several days. *Reepithelization* is critical for restoration of the barrier function of the wound. This begins within 24 hours of injury as a migration of epithelial cells from surrounding wound margins. *Granulation* tissue consists of inflammatory cells, fibroblasts, and neovasculature in a matrix of fibronectin and other glycoproteins, glycosaminoglycans, and collagen. Its formation involves the synthesis of collagen and noncollagen matrix components and the generation of a new vascular system to support growth. *Wound contraction* (the centripetal movement of the wound edges) is a critical event during the granulation tissue formation period.

The final phase of wound healing is the remodeling phase. Collagen is remodeled and reoriented. Myofibroblasts cause wound contracture. Tensile strength of the wound plateaus. This process will not be complete for approximately six months following injury. Finally, for months after scar and matrix are formed they are *remodeled* with the ultimate goal to decrease the bulk of the scar and improve its tensile strength through realignment of the collagen fibers.

Factors influencing wound healing

Patient/disease factors

There are a number of factors that affect wound healing which include genetic disorders, such as Ehlers-Danlos syndrome, osteogenesis imperfecta, and many others, as well as metabolic factors such as diabetes mellitus or chronic renal failure and genetic "over-healing" states such as hypertrophic scars or keloids.

Diabetes affects wound healing in multiple ways. Microangiopathy diminishes oxygen delivery, and inslin deficiency is particularly significant in early wound healing phases, when leukocyte function is defective. Low insulin states also lead to defective collagen synthesis.

Hypertrophic scars and keloids are "over-healing" states. These lesions are caused by excessive production and deposition of collagen and glycoprotein without equivalent degradation. Hypertrophic scars are elevated and remain within the original tissue injur site. They tend to regress with time. In contrast, keloids overgrow the boundaries of the original injury and invade the surrounding normal tissue. Treatment of both hypertrophic scars and keloids is directed toward inhibiting collagen overproduction – with intralesional steroids, and occasionally excision with postoperative pressure dressing, silivon gel sheeting, interferon-α2b, or radiation.

Local Wound Factors

There are a number of wound factors which influence the healing process – these include infection, tissue trauma, tissue ischemia, wound closure techniques, and wound dessication.

A bacterial wound infection is probably the most common cause for prolonged healing. All wounds are contaminated postoperatively by resident bacterial flora. Clinical infection ensues when a critical number of pathogenic organisms are present. Bacteria slow healing by activating the alternate complement pathway and detrimentally exaggerating and prolonging the inflammatory phase of wound healing. In addition, they elaborate toxins and proteases that can be damaging to cells. Finally, they compete for oxygen and nutrients in the wound matrix. Lactic acid is produced in this hypoxic state and further stimulates the release of damaging proteolytic enzymes.

Incisions in the head and neck region should be made with the sharpest blade available. The scalpel should incise the skin at right angles, except in hair-bearing areas where the incision should be parallel to the hair follicles.

The rough handling of tissue and the use of inappropriately bulky instrumentation can lead to crushed skin edges and subsequent devitalization of tissue. This increases the inflammatory reaction around the wound and the chances for secondary infection. Likewise, wounds closed with inappropriately reactive suture material may increase the likelihood of a clinically apparent foreign body reaction and subsequent infection. Skin sutures tied too tightly may lead to tissue ischemia and predispose to infection

Excessive bleeding and the formation of a hematoma within the wound not only can mechanically disrupt the wound closure but also can serve as an excellent culture medium for

microorganisms. Meticulous hemostasis attained at the time of surgery, along with primary obliteration of dead space should preempt the need for drains in most cases.

Scar Analysis

An ideal scar, following complete healing and maturation, should possess all of the following characteristics. It should be (1) flat and level with the surrounding skin; (2) of good color match with the surrounding skin; (3) narrow; (4) parallel to RSTL; and (5) without straight, unbroken lines that can be easily followed with the eye.

Scars that are amenable to revision are (1) widened; (2) perpendicular to RSTL; (3) interrupting an aesthetic unit of the face; (4) webbed, (5) pin-cushioned; (6) hypertrophied; (7) adjacent to, but not lying in, a favorable site; (8) long, unbroken, and not within RSTL; or (9) causing distortion of facial features or anatomic function. As a guideline, any scar that is wider than 2 mm or longer than 20 mm is a candidate for revision.

Timing of Scar Revision

The timing of scar revision is variable. Every scar will show some improvement for up to 1 to 3 years without revision. Traditionally, patients were told to wait 6 to 12 months before discussion revision of a scar. That is still true of scars that are thin, in favorable locations, or are of a natural configuration that the surgeon knows will lend itself well to camouflage with maturation. Patients can actively participate in the healing process of their scars by gently massaging the scar beginning at approximately 1 month postoperatively. This procedure can hasten resolution of the firm texture associated with newly healing wounds. A scar that is uneven, shows a marked step-off, or is obviously poorly positioned may be revised as early as 2 months after the original closure. If it is possible to tell early that a scar will not improve with maturation, there is not a compelling reason to make the patient wait. In fact, early revision with realignment of the scar may allow it to mature more rapidly.

Relaxed Skin Tension Lines

Relaxed skin tension lines are those lines that follows the furrows formed when the skin is relaxed. Unlike wrinkle lines, they are not visible features of the skin. They can be found by pinching the skin and observing the furrows and ridges that are formed. Pinching is the most reliable method of finding the RSTL. The forces that cause the RSTL are inherent to the skin itself and the underlying collagen matrix. Although each person has his or her own blueprint for RSTL, the direction of tension lines between individuals is consistent.

The RSTL correspond to the directional pull that exists in relaxed skin. This pull is determined largely by the protrusion of the underlying bone, cartilage, and tissue bulk that the skin covers. Although the RSTL are not caused by the underlying facial musculature, they frequently run perpendicular to them. The RSTL exert a constant tension on the face when it is in repose, even during sleep, and are altered only temporarily by muscle contraction. It is for this reason that incisions made parallel to tension lines heal better than those made tangentially to tension lines.

Excisional Techniques

Scar Repositioning/ Fusiform Excision

When presented with wounds that were not closed properly, reexcision with meticulous closure may be all that is needed. Reexcision should be done by use of fusiform shape with 30-degree-angled ends positioned within RSTL when possible. A slight vertical bevel outward from the original scar will prepare the wound edges for proper everted closure. Routine undermining of 1 to 2 cm around the periphery of the wound will allow reapproximation of the skin edges with minimal tension. The use of buried subcutaneous sutures will further decrease wound edge tension. Final eversion of the wound edges is achieved with properly placed monofilament interrupted sutures. Vertical mattress suture can also prove helpful when wound edge eversion needs to be maximized.

These excisions should be performed on a hypertrophied scar lying within the RSTL. Certain scars may be amenable to fusiform excision and direct closure. These would classically be short scars that are oriented in the RSTLs but which are unacceptable for some other reason. One should try to keep the angle at the end of the excision less than 30 degrees.

This technique is useful for existing scars, such as pitted acne scars or pox scars, that can be excised, with the tradeoff being a pit for a small, straight-line scar that falls within RSTL. Small, existing scars that lie close to RSTL or another favorable site may be repositioned with excision and undermining techniques. Scars on the midface can sometimes be moved to the nasolabial crease, those on the forehead to the hairline, and those on the lateral cheek into the preauricular crease. However, if the symmetry of the facial contour is grossly distorted by this pseudo-rhytidectomy care should be taken to "tighten" the contralateral facial features.

Meticulous attention must be paid to closure in fusiform excision, and care should be taken to follow the natural skin lines as they gently curve, rather than creating a straight line where none normally exists

Serial excisions

Serial excision of scars may be appropriate for scars that are near an anatomical boundary or for large unsightly scars, such as after a split-thickness skin graft. For a scar that is oriented correctly near but not in a boundary line between facial aesthetic units, excision of the intervening skin may move the scar to a more camouflaged location. If the intervening skin is too much to excise in a single session without causing undue distortion, the tissue may be excised in a staged fashion, with post-operative massage and the passage of time allowing for tissue stretch and relaxation. Large areas covered by skin grafts may be reduced or eliminated over time as the staged serial excisions allow native tissue to expand and adapt to the new arrangement. By removing a portion of the lesion and advancing only the normal adjacent skin, the lesion can, over several procedures, often be totally eliminated.

Tissue expanders may be useful in serial excision. If they can be placed in such a way that only normal skin is expanded, more coverage may be obtained with each surgical procedure. Studies on the gain of surface area afforded by the three most commonly shaped expanders have

determined that rectangular expanders provide the greatest expansion at 38%, crescent-shaped expanders provide 32%, and round provide only 25%.[12] As a general rule, the base of an expander should be approximately 2.5 to 3.0 times as large as the area to be reconstructed.[1]

Shave excision

Raised, narrow scars may be amenable to a simple shave excision of the scar down to the level of the surrounding tissue.

Irregularization and Camouflage

Z-plasty

Z-plasty is the oldest, simplest, and most versatile of the zigzag closures. The Z-plasty has been described for use in scar elongation, for release of scar contracture, and for changing the direction of a scar. The Z-plasty serves to reorient and lengthen a scar. As such, it is ideal for scars which are in an unfavorable orientation and are contracted. The two triangular flaps are transposed relative to each other to effect the change. It is used to create irregular zigzagging lines, which make the scar less visible. It also changes the direction of scar from conspicuously perpendicular to the RSTL, and converting it parallel to the RSTL. Third, it has the distinct advantage of lengthening a contracted scar. This point is particularly important with visible deformation of free margins, including the eyelid, nasal alar rim, and lip. Finally, this technique is used to change a displaced anatomic point, raising or lowering it.

Two arms that are of the same length as the common diagonal are extended from the ends in opposite directions. The “angle” is determined by the angle between arm and common limb. The angle of the designed triangle determines the degree of tissue lengthening, with larger angles resulting in greater gains. The length of the central diagonal also determines tissue gain, but this aspect is less variable because it is usually predetermined by the length of the scar. The classic 60° Z-plasty angle results in a 90° change in scar direction and a 75% gain in tissue length. Z-plasties employing other angles are used, most commonly with two 30 degree angles yielding a 25% length increase or two 45-degree angles giving a 50% increase in length. The more obtuse the angle, the more the original horizontal limb is lengthened after flap transposition. Angles less than thirty degrees should be avoided as one risks tip necrosis, and angles larger than sixty degrees make transposition of the flaps difficult due to tissue limitations. Angles larger than sixty degrees can be affected by bisecting them into smaller-angled flaps and performing a four (or even six) flap Z-plasty.

Z-plasties are useful in breaking up straight-line scars that cross RSTL. Multiple Z-plasties are often useful in the revision of small flaps on the face that may have healed with a pin-cushioned appearance. Placing several Zs around the curve of the flap, allowing interdigitation of flap skin with adjacent skin, provides excellent camouflage, especially when later followed by light dermabrasion.

Besides the irregularization of a scar that can be achieved with Z-plasty, this technique also serves to neutralize the forces acting to cause contracture of a straight-line wound, spreading the forces over several directions allowing little tension in any single direction.

W-plasty

W-plasty is an irregularization technique used to treat antitension line scars and consists of excising consecutive small triangles on each side of a wound or scar and imbricating the resultant triangular flaps. The advantages of a W-plasty are that it generally employs segments with shorter limbs than Z-plasty and does not cause overall lengthening of a scar. Its usefulness is greatest on the forehead, cheeks, chin, and nose, while the Z-plasty is more appropriate to areas about the eyes and mouth. One disadvantage of the W-plasty is that it requires the excision of small amounts of skin and, therefore, allows no gain of tissue in tight areas. These techniques are usually suited for long scars. They may also be useful in planned incisions that out of necessity are perpendicular to RSTLs to irregularize the edges and provide small segments that are more in line with the RSTLs.

Unlike multiple Z-plasties, a W-plasty does not involve transposition of flaps. It merely serves as a regularly irregular closure of a scar. One should try and align some of the sides into the RSTLs as much as is possible. This technique is particularly useful on curved scars.

The technique begins with the marking out of a series of consecutive triangles (w's) along the wound or scar edge. The arms should be between 5 mm and 7 mm in length, and one arm of the triangle should be drawn in parallel to the RSTL. After excision of the triangles, superficial undermining of adjacent tissues is performed, and the triangular shaped flaps are then imbricated. Care should be taken to preserve the subcutaneous scar tissue, because this can provide a stable bed for new scar healing.

Geometric Broken Line Closure

The geometric broken line closure (GBLC) is a scar irregularization technique with a bit more sophistication than the W-plasty. The design of GBLC comprises a series of random, irregular, geometric shapes cut from one side of a wound and interdigitated with the mirror image of this pattern on the opposite side. The triangles, half-circles, rectangles, and squares should all be between 5 -7 mm in any dimension for improved camouflage. GBLC is an excellent technique of scar revision that creates an "irregularly irregular" scar without affecting its length. The geometry of the resultant scar is less predictable by the casual observer's eye and frequently goes unnoticed. The GBLC is most useful for long, unbroken scars that cross RSTL.

This technique is particularly well suited to scars that traverse broad flat surfaces such as the cheek, malar, and forehead regions. As in running w-plasty, the length of the geometric shapes is between 5 mm and 7 mm. Similar principles of undermining and leaving deeper scar tissue in the bed of the wound are adhered to as previously described. Closure of a GBLC is facilitated by careful dermal suturing to remove tension from the skin, and by the use of a running, locked skin suture. Two-layered closure is performed, and the suture line is often reinforced with adhesive medical strips. The patient is typically seen back in 1 week for suture removal, with repeat taping of the wound edges for the next 2 weeks.

As with Z-plasty and W-plasty, dermabrasion 6 or more weeks after GBLC provides optimal camouflage. The GBLC is time consuming to execute and, if improperly designed, can worsen a scar, but there are few other disadvantages to its use.

Adjunctive Techniques

Dermabrasion

Dermabrasion superficially abrades the scar and the surrounding skin to the level of the papillary dermis in a precise and controlled manner. This process results in a smoother texture and evens out any irregularities along the scar surface. Dermabrasion can improve the appearance of uneven scar edges and raised grafts and flaps by leveling the irregular contours. The best candidates for dermabrasion are those with lighter complexions, because the risk of postabrasion dyspigmentation is lowest in these individuals. It is prudent to avoid dermabrasion in patients with human immunodeficiency virus or hepatitis because of the risks to personnel from airborne pathogens. The use of 13 cis-retinoic acid and its affect on healing after dermabrasion has been debated .

There are two main techniques for dermabrasion. For larger areas, a motorized dermabrader with a diamond fraise tip allows for a more even and controlled depth of ablation. A topical spray cryogen serves to anesthetize the skin and harden it, making it more receptive to dermabrasion. Preparation of the area to be dermabraded can also be accomplished with local anesthesia both for nerve block and infiltration. Infiltration not only provides anesthesia but can also cause distention of the skin, which aids in the technique. Preferably, local anesthetic *without* epinephrine is used to allow for more clear visualization of capillary bleeding that is seen with dermabrasion. The handpiece is generally held 90 degrees to the direction of wheel rotation and is advanced at right angles to the direction of wheel rotation. Smaller scars, however, can be lightly dermabraded to the point of pinpoint bleeding using sterile 300- to 400-grit sandpaper.

The surgeon must be cautious not to go too deeply into the dermis, thus causing a depression that would be difficult to repair. A second dermabrasion can always be performed if the initial procedure is not enough. As one enters the superficial papillary dermis, small capillary loops are identified as pinpoint bleeding. As the papillary dermis is penetrated more deeply, small parallel strands of white-colored collagen can be appreciated. Once this is seen, dermabrasion has been taken to the appropriate depth. Preservation of the reticular dermis with its adnexal structures will allow for the proliferation of undamaged epidermal cells across the abraded surface. The periphery of the treated area should be feathered with fine diamond fraises to allow for a smooth transition between treated and untreated areas.

The boundary of the dermabraded area should be extended beyond the scar and feathered into normal surrounding skin to include an entire cosmetic unit or subunit. The pigmentation and texture may differ between the treated and untreated areas, leading to a more conspicuous treated area. The blending helps to prevent this demarcation

Shallow, crater-like facial scars are often treated with dermabrasion. The scar is not removed, but the surrounding tissue is brought down to a level closer to that of the depressed region. This allows the lesion to blend into the surrounding normal skin because less of a shadow is created by the depression to draw attention to the scar. Mildly elevated immature scars also benefit from localized dermabrasion.

Dermabrasion can be used in conjunction with other scar revision techniques in a

sequential fashion. As stated previously, running Z-plasty, W-plasty, and GBLC are generally followed at 6 to 12 weeks by dermabrasion to better blend the new scar with the surrounding skin

Laser resurfacing Techniques

Ablative vs Non-ablative Lasers

Pulsed ablative lasers (eg, carbon dioxide and erbium: YAG) can provide similar results as dermabrasion by superficially ablating the scar. Each laser has its distinct advantages. Erbium:YAG, with its higher affinity for water, is more precise in ablating raised scar edges. The carbon dioxide laser causes more thermal necrosis, which promotes more wound contraction and collagen remodeling. This collagen remodeling is an important aspect of the ablative procedures because it is not just the physical leveling of the scar that enhances the appearance of the scar. Surgical scar revision and laser resurfacing can sometimes be combined into a single-step procedure in which the cosmetic unit surrounding the scar undergoes laser treatment first, immediately followed by scar re-excision. This procedure allows the entire area to re-epithelialize and remodel at the same time.

All ablative procedures that include lasers and dermabrasion may result in pigmentary alteration and carry the risk of worsening a scar from overaggressive treatment. At a minimum, patients should be warned of the prolonged recovery course, which sometimes may be longer than the initial surgery. Patients need to be fully informed and provide their consent for these potential risks.

Nonablative lasers are used to treat scars and have the advantage of improving scars without incision or wounding, thereby minimizing downtime. Multiple lasers have been used to refine scars, and practically any nonablative laser that heats collagen can effectively improve the appearance of a scar. The flashlamp-pumped pulsed dye laser, however, has been used most extensively. The pulsed dye laser works through absorption by oxyhemoglobin, causing direct destruction of the blood vessels and an indirect effect on the surrounding collagen. This vascular laser improves the overall redness caused by the scar's vascularity and promotes collagen remodeling and scar softening. The collagen remodeling is most effective at lower subpurpuric fluences where collagen is believed to be stimulated rather than injured. It is probably best suited for red hypertrophic scars or for telangiectases surrounding scars, which typically are not noticed for at least 1 month postoperatively. Recent reports, however, have shown improvement of the final scar appearance when the laser treatment is initiated at the time of suture removal. Newer nonablative lasers with wavelengths of 532 nm, 1064 nm, 1390 nm, and 1450 nm are also being used to promote collagen remodeling

Intralesional Steroids

Hypertrophic linear scars, and bulky grafts and flaps, can be treated with intralesional corticosteroids. Injections can be instituted at approximately 1 month postoperatively. A small amount (as little as 0.1 mL) of low-dose triamcinolone acetonide (Kenalog) at 5 to 10 mg/mL is injected into the scar; this dosage can be repeated monthly until the scar has flattened. This treatment will not affect the width of the scar, however. The injection is placed into the bulkiest region of the scar, at the level of the deep dermis or subcutaneous fat. The physician must be

cautious not to be overly aggressive with the quantity, frequency, or strength of Kenalog injections, because significant atrophy may occur, especially if the injection leaks out into healthy skin. Steroids can cause hypopigmentation and telangiectasias when injected in higher concentrations into the dermis. Also, one should avoid the injection of steroids into the subcutaneous fat, because this can lead to deformity from fat atrophy.

Conclusions

Scarring is an inevitable and necessary aspect of healing. There are many techniques that can be utilized for scar revision and prevention. An appropriate knowledge of skin physiology and biomechanics, facial aesthetic principles, and the surgical geometry of soft-tissue surgery can help minimize the scarring that may occur with patients or help revise the scarring that they endure from other causes.

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