

Review Article

Scar revision

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ABSTRACT

Most surgical patients end up with a scar and most of these would want at least some improvement in the appearance of the scar. Using sound techniques for wound closure surgeons can, to a certain extent, prevent suboptimal scars. This article reviews the principles of prevention and treatment of suboptimal scars. Surgical techniques of scar revision, i.e., Z plasty, W plasty, and geometrical broken line closure are described. Post-operative care and other adjuvant therapies of scars are described. A short description of dermabrasion and lasers for management of scars is given. It is hoped that this review helps the surgeon to formulate a comprehensive plan for management of scars of these patients.

KEY WORDS

Suboptimal scar, scar management, surgical scar revision, scar adjunct therapy

INTRODUCTION

Scars are an integral part of human life. They find mention in history as well as literature. Rana Sanga's innumerable scars were testimony to the many battles he fought and survived while Harry Potter's "lightning bolt" scar captured the imagination of an entire generation. Indeed, one scar borne by the entire humanity – the umbilical cicatrix is not just acceptable but highly desirable.

Why then do patients come to plastic surgeons seeking disappearance of their scars? A scar may impede function – as in case of a contracture running across a joint. A scar may cause discomfort, tightness or even pain.

A scar may cause cosmetic deformity and the patient may seek treatment merely to "look more normal." The scar may be an unpleasant reminder of a traumatic past and the patient may seek to erase its memories by erasing the scar. Finally, the patient may associate the scar with a personal failure – inability to impress a girlfriend or inability to get promoted – and may be looking at treatment of the scar as a means of success in his/her endeavors.

After proper assessment and adequate counseling, it is our duty to offer the patient rational treatment options which have good clinical evidence. It is vitally important to counsel the patient about the expected outcome. In this article, we review various treatment options for scars and an attempt is made to help the reader make a treatment plan for his/her particular patient.

SUBOPTIMAL SCARS

An ideal scar is thin and flat, has a good color match with the surrounding skin, is oriented along the relaxed skin tension lines (RSTLs), and does not produce any distortion of adjacent tissues.

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Any scar that does not fit the above definition is a suboptimal scar. Every attempt should be made to convert a suboptimal scar into an ideal scar although it may not be always possible.

Scars can be classified as - ^[1]

Mature scar – A light colored flat scar.

Immature scar – A red, sometimes itchy or painful, and slightly elevated scar in the process of remodeling. Many of these will mature normally over time.

Linear hypertrophic scar (e.g., due to incision) – A red, raised, sometimes itchy scar confined to the border of the original incision. These scars may increase in size rapidly for 3-6 months and then, after a static phase, begin to regress. After maturation, they may have an elevated, slightly rope like appearance with the increased width.

Widespread hypertrophic scar (e.g. due to burns): A widespread red, raised, sometimes itchy scar that remains within the borders of the original injury.

Minor keloid – A focally raised, itchy scar extending over normal tissue. This may develop up to 1 year after injury and does not regress on its own.

Major keloid – A large raised (>0.5 cm) scar, possibly painful or pruritic and extending over normal tissue. This may result from minor trauma and can continue to spread over years.

In addition to the above mentioned varieties, scars may also be atrophic, depressed, hypopigmented, hyperpigmented, or irregular with nodularity.^[2]

Vancouver scar scale is the most commonly used scale to assess scars.^[3]

CAUSES OF A SUBOPTIMAL SCAR

Factors that are associated with a suboptimal outcome can be divided as wound factors, patient factors, and surgeon factors.

Wound factors

- Wide wounds that are primarily closed give a poorer scar due to tension on the suture line^[4]
- Infected wounds give a poorer scar^[5]

- Traumatic and excisional wounds fare poorer than surgical incisional wounds^[6]
- Wounds oriented across the RSTLs fare poorer than those along the RSTLs^[7]
- Location on trunk and extremities give poorer scar than the head and neck region.^[6]

Patient factors

- Children develop poorer scars than older patients due to higher elastin content of their skin leading to higher tension at the skin edges.^[8]
- Patients with systemic diseases like Diabetes Mellitus, Chronic Renal Failure, or those on Immunosuppressants are more susceptible to wound infections and poor wound healing.^[9]

Surgeon factors

- Inappropriate technique – Traumatizing the edges, Use of electrocautery, Suturing under tension etc.^[6]
- Level of training of the surgeon.^[10]
- Inappropriate post-operative care (discussed subsequently).

SCAR REVISION

Prevention

Treatment of a scar begins before suturing the wound! Proper care should be taken at the time of initial laceration repair in case of traumatic wound and before creation of the incision in case of surgical incisions. Preventing a suboptimal scar is much easier than treating a suboptimal scar.

A surgically created incision should be a clean cut incised wound through the epidermis and dermis. The incision should ideally lie along the RSTL. If the incision can be planned in a staggered manner (viz. multiple Z plasty, Geometric broken line etc.), it should be planned so. Use of cautery should be minimal near the wound edges. Before contemplating closure, all dead space should be obliterated and accurate hemostasis should be achieved.

In case of a traumatic laceration, adequate debridement and copious irrigation with normal saline or sterile water should be done to remove all devitalized tissue and debris.^[11] These two maneuvers are essential to prevent wound infection. The traumatized wound edges should be excised so as to convert the wound into a clean cut incision and then closure should be attempted.

The aim of wound closure should be to obtain a pencil-line thin scar which is inconspicuous by aligning it along the natural creases.

PRINCIPLES FOR SUTURING A WOUND

The principles of proper wound closure have been in existence since a long-time^[12] and these have been subsequently validated.^[13,14] They can be summarized as follows:

Atraumatic technique

Wound edges should be handled gently. Use of thumb or skin hooks to provide counter traction while passing the needle is preferable than traumatizing the edge by gripping it tightly with a toothed forceps. Trauma to the wound edge either by the holding forceps or by the cautery increases tissue damage which in turn increases the inflammatory response and causes poor scarring.

Tensionless closure

A wound closed with edges under tension gives a scar which is thin and wide. This not only gives a bad cosmetic appearance but also gives a weak scar that is prone to breakdown. Use of buried deep dermal sutures to take away the tension from the epidermal edge is advocated.

Prevent strangulation

Sutures should be tied loosely so that the edges should just lie next to each other. Tight suturing strangulates the tissues, impeding the blood supply, and ultimately causing a bad scar. It also leads to ugly hatch marks causing a rail road pattern.

Proper skin edge eversion

Inverted edge after suturing again gives a poor appearance after the suture removal. Eversion of skin edge is also an indicator that the wound edges are lying next to each other without any tension. Final approximating sutures should be simple stitches which are flask shaped or horizontal mattress sutures so that edges are everted.

Alignment of skin edges

A situation may be encountered where in the two edges have different thickness or are at different level. The thickness of suture bites should be adjusted in such a case to ensure that finally the edges are appropriately brought together and not overlapping each other.

Restoration of anatomical landmarks

All efforts must be taken to ensure that the suturing does not produce distortion of important anatomical landmarks like the eyelid (producing ectropion), ala of nose or the eyebrow. If during primary suturing it is apparent that there is undue pull on such important structures, then a primary local flap or a Z plasty is indicated. Distorted facial features produce a much worse appearance than a longer scar!

Reorientation along lines of tension

All efforts must be taken to ensure that the ultimate scar lies along the RSTL. A primary Z plasty may help re-orient the scar along RSTLs.

Dog ear correction

Any dog ear forming at the time of suturing should be excised at that time itself. A dog ear that is not corrected at the time of primary surgery will never correct itself post-operatively. A strategy to prevent dog ears forming is by starting to suture from periphery to center.

Scar irregularization

Contractile forces act perpendicular to the long axis of the scar. Irregularization of the scar creates multiple vectors in opposite directions, thus dispersing the contractile forces into multiple axes. This prevents scar widening, tissue deformation, and scar contraction. An irregular scar is less conspicuous than a straight or a regular patterned one.

The above mentioned principles hold true not only for primary repair of lacerations but also for doing a scar revision.

METHODS OF SCAR REVISION

Scar excision and resuturing

If it is apparent that the poor scar is a result of poor technique or post-operative infection, then simple excision of the scar and resuturing using the above principles may be helpful in attaining a good appearance. Adjunct therapy is initiated as described later.

Z plasty

It is a double transposition flap where the scar to be excised lies along the central limb of the Z with two peripheral limbs parallel to each other. After transposition, the central limb will be perpendicular to the original central limb.^[15,16]

Indications of Z plasty

- Scars greater than 30 degree off the RSTLs.
- Scars that are contracted.
- Scars that form web.

The Z should be designed such that the orientation of the final scar is in a more favorable position with respect to the RSTL.

While designing a Z plasty the ideal angle of the Z plasty should be 60° with both peripheral limbs equal in length to each other and to the central limb.

Using Pythagorean Theorem, Limberg^[17] showed the theoretical gains obtained from a Z plasty. Practically, however the gains in length are less because of tissue elasticity.

Thus, higher angles lead to higher gains in length but at the expense of transverse shortening leading to undue transverse tension on the scar. With smaller angles, the transverse shortening is less but gain in length is less and the flap tip vascularity may be compromised. Hence, a compromise between the two, the ideal angle to be used is 60°.

Rather than doing a single Z plasty, performing multiple Z plasties along the entire length of the scar has advantages:

- Makes the scar irregular, thus makes it less conspicuous than a single straight line.
- Creates multiple and different vectors of tension which helps to prevent scar widening and contracture.
- There is less need for large peripheral limbs.
- More length can be gained with less transverse shortening.

Disadvantages

- The scar becomes longer.
- There are at least two additional scars.
- At least some part of the ultimate scar may not lie along the RSTL.

The principle of the Z plasty can be used in designing different flaps like the Limberg's four flap Z plasty,^[17] Planimetric Z plasty,^[18] and Mustarde's jumping man flap.^[19] Figure 1 shows the diagrammatic representation of a single and multiple Z plasty.

W plasty

It is designed to make a linear scar irregular, such that majority of the limbs lie along RSTL.^[16,20,21]

While performing the W plasty, some amount of normal tissue is excised along with the scar such that the final scar is irregular, in the shape of multiple W's lined side-by-side.

Indications

- Short scars running across the RSTL.
- Scars/incisions on curved surfaces like mandible.
- Scars/incisions in concavities e.g. web space.

It should be done only in areas where there is lateral tissue laxity, e.g., forehead, temple, chin, cheeks etc.

The W plasty consists of multiple small triangular advancement flaps on either sides of the scar such that the closure occurs in an interdigitating fashion. Designing the ends of W plasty so as to prevent forming a dog ear can be a little tricky. Shortening the limbs of the W as we approach the end of the excision helps in achieving good closure. The terminal portion should be designed such that there is a 30° angle at each end. Alternatively, fusiform excision perpendicular to the terminal limb of W at each end can be done. Figure 2 shows the diagrammatic representation and Figure 3 shows the clinical application of W plasty.

Advantages

- Easy to plan and execute.
- Breaks a straight scar into multiple small segments many of whom lie along the RSTL.

Disadvantages

- Needs adjacent tissue laxity.
- Regular repetitive pattern – makes the scar noticeable.
- Scar may become longer.

Geometric broken line closure

It is designed to convert a long linear scar into a randomly irregular scar.^[16,22]

Interdigitating geometric lines are drawn in such a manner that triangles, rectangles, squares, and even semicircles are created on either side of the scar in a random

Angle of lateral limb of Z-plasty (degree)	Theoretical gain in length of central limb (%)
30	25
45	50
60	75
75	100
90	120

fashion. Majority of the lines should lie along the RSTL. After excision along these lines, the advancement flaps from both sides interdigitate so as to create a randomly irregular scar. Like in W plasty, ends have to be closed using 30° angulations to prevent the dog ear which may occur if higher angles are used. Alternatively, a fusiform excision should be done at the end perpendicular to the terminal limb of the excision.

A practical way of performing a geometric broken line closure is – A dotted line is drawn around the scar and another concentric line 5 mm around this inner line. Multiple randomly placed interdigitating geometric figures are then drawn within these two lines such that the ends merge into angles less than 30° to create a randomly irregular pattern after closure. Figure 4 shows the diagrammatic representation and Figure 5 shows the clinical application of Geometric broken line closure.

Advantages

- It has all advantages enumerated above of breaking a linear scar into multiple small segments.
- In addition, the irregular random pattern makes the scar less conspicuous than W plasty or multiple Z plasty.

Disadvantages

- It is difficult to plan and execute.
- Excision of normal tissue means that it should be done only in areas where there is excess laxity of tissues.

Subcision and fillers

Some scars may be depressed due to tethering of the skin to deeper tissues or scarring in the deeper tissues. In such a case, breaking the fibrous septae with a subcision spatula or even a 16 or 18 gauge needle can free the skin. The hollow is then filled with soft tissue fillers, acellular dermis, or autologous fat to correct the contour deformity.^[23,24]

Autologous fat is preferred for a variety of reasons. It is inexpensive, plentifully available and permanent. The fat derived stem cells present in the injected fat may also improve the quality of overlying skin and give a better result.^[25,26]

Multistage treatment of wide scars

Wide scars (e.g., those due to burns) may not be amenable for a single stage procedure as primary closure may not

be possible after excision.^[27] Such scars can be managed by serial excision or tissue expansion.

During serial excision, the margins of the scar are excised and the surrounding normal tissue is undermined and advanced. How much can be safely excised during each

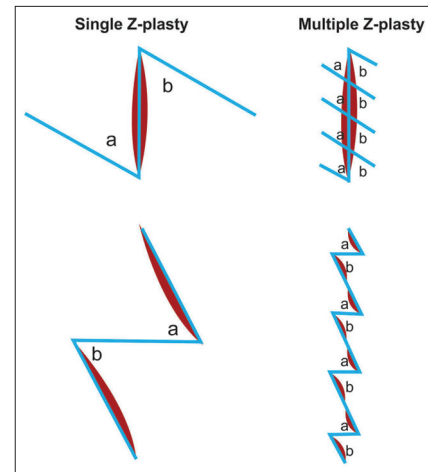


Figure 1: Diagrammatic representation of single and multiple Z plasty. Note how the scar is broken up by the multiple Z plasty

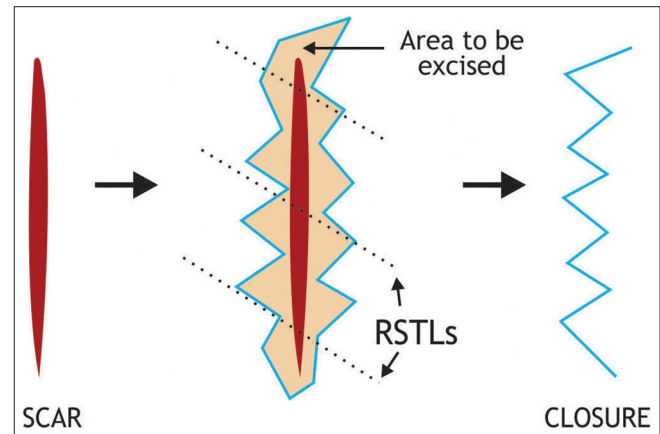


Figure 2: Diagrammatic representation of W plasty



Figure 3: Traumatic facial scar treated by W plasty shows good appearance after 1 year post-surgery and hair restoration

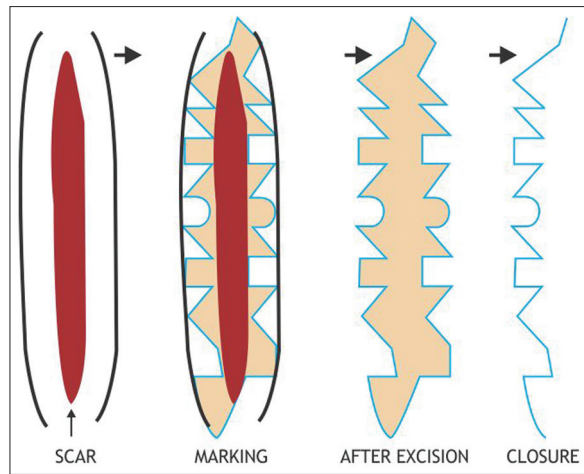


Figure 4: Diagrammatic representation of geometric broken line closure

stage depends on the pliability of surrounding tissues. Excision stages should be planned such that the final scar lies along a RSTL.

Tissue expansion followed by excision of scar and advancement of the expanded skin flap is a useful technique for wide scars. Figure 6 shows the clinical application of tissue expansion in management of wide scars which after excision would lead to significant tissue loss. Large areas can be covered with similar tissue (thus giving better aesthesis) with only two surgeries. However, complications such as infection, exposure, and extrusion may happen. It takes time for expansion and while expanding the tissues, there is an unsightly bump.

A full account is beyond the scope of this article.

Scar excision and cover (skin grafting or flap cover)

Widely scarred areas can be treated by excision of the entire scar and providing cover by split skin graft (SSG), full thickness skin graft (FTSG), or a flap.

SSG can cover large areas but gives a poorer aesthetic appearance than FTSG or a flap. Hyperpigmentation, contraction, poor skin quality, and lack of adnexal structures are all problems associated with SSG. It may still give a better result than a large area of burns which has healed by secondary intention. Use of large uniform sheets without meshing improves the appearance.

FTSG retains all skin adnexal structures and is aesthetically better than a SSG but its utility is limited by paucity of donor areas which can be closed primarily. Take of a FTSG



Figure 5: Elevated facial scar managed by geometric broken line closure. The last frame shows appearance after 3 years (Photos courtesy Dr. Sundeep Vijayaraghavan)

is also precarious than SSG. It cannot provide bulk.

Flaps whether local, regional, or distant can provide both bulk as well as cover. They bring their own blood supply hence are a better option where the vascularity of the tissues is poor.

POSTOPERATIVE CARE

Nutrition

Wound dehiscence and other complications are common in patients with malnutrition that can be detected by a low albumin level.^[28] Various micronutrients (vitamins A, C, B, complex, Zinc, antioxidants *etc*) are essential for adequate wound healing and their supplementation may accelerate wound healing ultimately affecting scar outcome.^[29] Although not many studies have established role of nutritional supplementation on the ultimate scar appearance, it is prudent to ensure that a patient is nutritionally fit to achieve a complication free healing.

Dressings and other post op care

Wounds should be managed in a moist environment with occlusive or semi-occlusive dressings till epithelization is complete. This takes up to 48 hours in a sutured wound.

Pruritus can be managed by long acting anti histaminics like fexofenadine or loratidine which have less CNS side effects. Antihistaminics also have an antifibrotic effect on scars.^[30]

Sutures must be removed at appropriate time to prevent hatch marks and railroad track appearance. For facial wounds the skin sutures should be removed before 5 days and if needed the wound edges may be reinforced using steristrips.

Patients are advised to use sunscreen on the exposed parts of body to prevent hyperpigmentation of scars.

Silicone

Silicone gel sheet therapy is a proven method of preventing abnormal scarring in the post-operative wound.^[1,31,32] Treatment is started soon after the suture removal and continued till 3 months. It is most effective in the immature dynamic phase and not so in old established scars.^[32] Suggested mechanisms of action are tissue hydration, increase in scar temperature, induction of tissue hypoxia, or production of a local static field.^[33,34] Silicone also reduces mast cell activity, the level of interleukin 1, and extracellular matrix production, all leading to decreased collagen synthesis.^[32] Self-drying silicone gel has recently shown to be effective for preventing hypertrophic scarring.^[35] A recent Cochrane review cites 13 trials involving 559 patients and concludes there is evidence of a benefit of silicone gel sheeting as a prevention for abnormal scarring in high-risk individuals.^[36]

Pressure

Pressure garments have been found to be effective in preventing hypertrophic scarring in burns.^[37] Pressure for the prevention, control and correction of scar hypertrophy averages 24-28 mmHg, which is approximately equal to the capillary pressure (25 mmHg). Sustained pressure causes hypoxia which reduces collagen synthesis and shifts the balance in favor of collagenase activity thus flattening the scar.^[38]

OTHER ADJUVANT THERAPIES

Intralesional injection of long acting steroid like triamcinolone is a well-established practice for managing

hypertrophic scar and keloids.^[39] Steroids produce a broad anti-inflammatory activity and reduce production of matrix proteins and collagen. This shifts the balance in favor of metalloproteases and collagenase which reduce the amount of scar tissue. Triamcinolone is given as monthly injection of 10 mg/ml or 40 mg/ml concentration.^[40] Side effects like skin atrophy, telangiectasia, delayed wound healing, and depigmentation are the limiting factors.

Intralesional injection of 5FU either as monotherapy^[41] or in combination^[42] has been shown to be effective for management for hypertrophic scars and keloids.

Once the healing is complete, massage of the scars may ameliorate the pain, itching and anxiety;^[43] however there is insufficient evidence that by itself it improves the outcome of scars.

Injectable or topical verapamil (5% cream) is reported for managing old inactive hypertrophic scars but needs more clinical studies for validation. It acts by inducing production of collagenase and thus hastens scar degradation.^[44]

Other topical applications like onion extracts, vitamin E, and imiquimod cream either have insufficient evidence of their benefit or have unacceptable side effects and hence are not recommended for routine use.^[45]

Radiotherapy and cryotherapy in combination with surgery offer good results in treatment of resistant keloids but their use for routine cases is tempered due to adverse effects in case of cryotherapy and potential risk of malignancy in case of radiotherapy.^[46]



Figure 6: A wide, post burn scar of face sustained during childhood. Tissue expansion was done followed by excision of scar, advancement of the flap and closure. The last frame shows result at 6 months

Emerging treatment modalities include topical anti TGF beta 1 and 2 antibodies, TGF beta 3 application, topical COX 2 inhibitors, angiotensin-converting enzyme inhibitors, minocycline, and gene therapy.^[46]

DERMABRASION FOR SCAR REVISION

Dermabrasion dates back to 1500 BC when sandstone was used in Egypt to revise scars.^[47] Modern dermabrasion is performed using a power source, hand piece, cord and a diamond fraise or a wire brush. Manual dermabrasion can be performed using sterilized sandpaper. Dermabrasion removes the epidermis and superficial dermis. It causes reorientation of collagen fibers parallel to the lines of wound tension, which may account for some of the scar contour smoothing effects noted after the procedure.^[48]

Timing

Dermabrasion is ideally done between 6 and 12 weeks post-injury. The wound has adequate tensile strength at this stage and the collagen remodeling is still active.^[49]

Pre op preparation

Isotretinoin (commonly used for acne treatment) should be stopped 6-12 months before dermabrasion to prevent hypertrophic scarring and keloid formation. Topical retinoic acid given 2 weeks prior to dermabrasion expedites re-epithelization and continued post-operatively prevents post-operative hyper pigmentation.^[50,51] History of tendency to hypertrophic scar and keloid formation should be ruled out.

Technique

Skin is held under tension either by tumescent infiltration or by mechanical stretching. The area to be dermabraded is stained with Gentian Violet. The pull of the dermabrader should be unidirectional and perpendicular to the plane of rotation of the hand piece. Initial pass should be made at 45° to the axis of the scar and subsequent passes should be made perpendicular to the initial pass. The presence of diffuse pinpoint bleeding indicates entry into papillary dermis. The presence of yellow chamiose colored parallel strands indicate entry into the superficial reticular dermis and frayed strands indicate entry into the deep dermis. Entry into the deep dermis should be avoided at all costs since it results in unacceptable scarring.^[50,52]

Post-dermabrasion care

Post-operatively, keeping wound in a moist environment helps re-epithelization which completes by 7-10 days.

This can be done by giving occlusive moist dressings or by frequent washing and application of ointment. Post-operative hyper pigmentation can be prevented by prescribing retinoic acid (0.05% cream once daily) and hydroquinone (4% topical cream twice daily).^[51] Avoiding sun exposure and using sunscreen is very important. Erythema lasts for a few weeks to months and can be decreased by the use of systemic or topical steroids.^[50]

LASERS IN SCAR MANAGEMENT

Laser generates heat in tissues after getting absorbed by a chromophore. In cutaneous scars, it causes selective photothermolysis of scar vascular supply, inhibition of fibroblast proliferation, and inhibition of collagen type III deposition.^[53]

Therapy with laser is optimally started between 4 to 8 weeks after the initial injury when the collagen remodeling is still in progress. In a recent study, it has been used immediately after suturing the wound and shown to have favorable result on appearance of the scar.^[54]

Traditionally, lasers used for scar resurfacing have been the CO₂ and Erbium YAG lasers. Because of differences in depth of penetration, the CO₂ laser is used for induction of contour changes and collagen remodeling in elevated scars and the Erbium YAG laser is used for generating subtle contour changes in depressed and atrophic scars. Their use is associated with longer epithelization times, and side effects like scarring, hypo, and hyper pigmentation.^[55]

Pulsed dye laser acts by the concept of selective photothermolysis and is absorbed by hemoglobin. Due to competitive absorption by melanin chromophore, it may not be suitable for use in dark toned individuals. It is used for treatment of red, hyperemic, hypertrophic scars, and keloids.^[55]

Newer fractional lasers^[56] prevent confluent epidermal damage, thus accelerating re-epithelization (within 1 day). Their chief advantage is superior adverse effect profile compared with conventional ablative lasers, including lower risk of scarring and dyspigmentation while being effective in skin resurfacing.^[57] The use of lasers for scar management is relatively new and larger studies are needed for establishing its role firmly.

Camouflage

Although many techniques are described to minimize

scarring, none can completely erase scars. Scar camouflage^[58] is helpful in cases where visible scarring exists even after all treatment options are exhausted or in the occasional demanding patient who refuses to accept even minimal residual scarring. Using color theory, opposite colored cosmetics can be used to conceal pigmentary changes in scar (green for an erythematous base, yellow for darkened or ecchymotic areas, or violet for sallow areas of collagen degeneration). Long lasting waterproof foundations are available.^[58] Hair styling can be used to cover many scars adjacent to and over the scalp. Scars in the hair bearing areas like eyebrows, moustache, beard or the scalp can be camouflaged by hair grafting.^[59]

SUMMARY

Abnormal scarring remains one of the major problems faced by surgeons and their patients. Surgical treatment of a suboptimal scar should be undertaken only after it matures, ideally after a year. A scar can be revised by excision and linear closure, Z plasty, W plasty, geometric broken line closure or excision and cover. Appropriate post-operative care and when indicated, adjuvant therapy form an essential part of the treatment plan. Laser, dermabrasion, and other adjuvant therapies mentioned in previous sections are useful in the management of immature scar. While some treatment modalities like

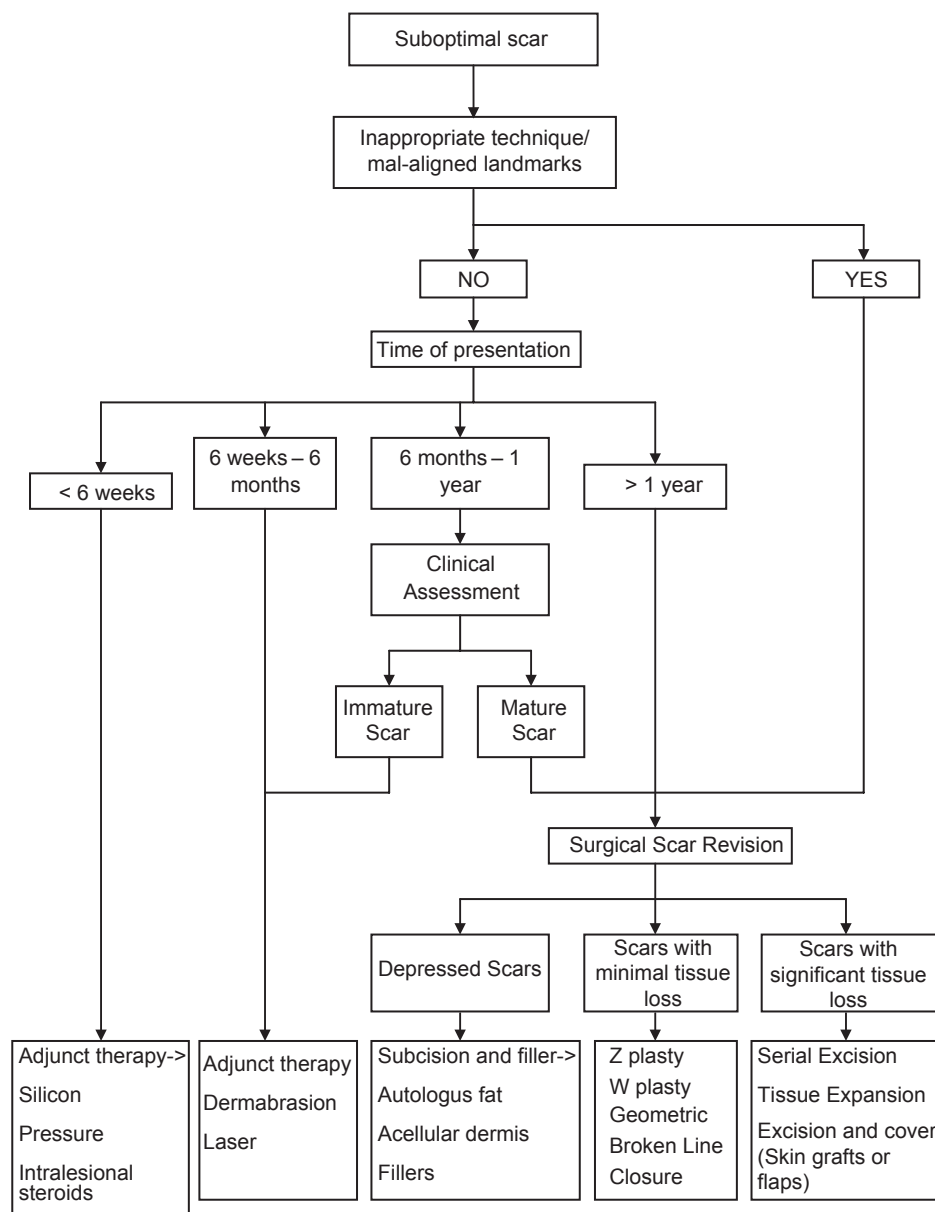


Chart 1: Algorithm for management of suboptimal scars

steroids and silicone gel sheets have adequate support in literature, others do not enjoy such support. Lack of well designed, large controlled trial is a major challenge in the study of management of scars. Emerging therapies hold promise in the future of scar management. In this article, we have presented an algorithmic approach for the management of suboptimal scars, which could be helpful in clinical decision making [Chart 1].

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