LASER TREATMENT OF HYPERTROPHIC SCARS, KELOIDS, AND STRIAE

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Despite increasing knowledge of wound healing and collagen metabolism over the past decade, scars and striae have traditionally been difficult lesions to eradicate. The millions of individuals affected by them have had little in the way of viable treatment options from which to choose until the last few years. Prior to the discovery that pulsed dye lasers could be used to safely and effectively treat scars and striae, treatments ranging from invasive surgical excisions and grafting procedures to dermabrasion, cryotherapy, corticosteroid injections, pressure therapy, and radiation therapy were used with varying degrees of success. Unfortunately, most of these treatments often were of little benefit or had side effects that were nearly as severe as the original scar. Even the use of vaporizing lasers such as the CO₂, argon, and neodymium:yttrium-aluminum-garnet (Nd:YAG) had to almost uniform scar recurrences. The more recent introduction of topical treatments, including retinoic acid and silicone gel, has produced waves of enthusiasm, but overall scar or striae effect has been minimal and slow to achieve. Similar results have been reported with the use of other occlusive dressings as well.

Beginning in the late 1980s, experiments using a vascular-specific pulsed dye laser on hypertrophic scars present within port-wine stains were initiated. Early in its use, it became clear that the 585-nm pulsed dye laser could affect more than its intended microvascular target. The laser-treated scars became more pliable and less hypertrophic, erythematous, and pruritic. These clinical observations were later substantiated by skin surface textural analyses, erythema reflectance spectrometry readings, scar height measurements, and pliability scores, all showing significant improvement with one or two laser sessions. Histopathologic examination of laser-irradiated scars confirmed the suspected improvement in dermal collagen (more fine and fibrillar post-laser treatment), but also pointed to a possible etiologic explanation for the laser’s effectiveness with the appearance of increased numbers of regional mast cells in the irradiated scars. As histamine has been shown to both positively and negatively affect collagen synthesis, its role in laser-induced scar improvement has yet to be determined. In addition, given the fact that mast cells also elaborate an intriguing variety of cytokines, their presence following laser irradiation and accompanying

*References 25, 31, 50, 55, 56, 65, 73, 75, and 78.

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tissue revascularization may provide an explanation for the therapeutic outcome following microvasculature destruction in terms of stimulating collagen remodeling. Other etiologic mechanisms include the possibility of collagen stimulation by dermal heat conduction from the irradiated blood vessels or lack of tissue oxygenation leading to collagen catabolism and release of collagenase.8, 22, 24, 47, 48, 53

Similarly, and perhaps not surprisingly, striae have also shown improvement after 585-nm pulsed dye laser treatment.10, 58. The fact that striae often demonstrate scar-like features with early erythema and late fibrosis could account for the significant improvement seen in some cases.21, 63

LASER TREATMENT OF SCARS AND STRIAE: BACKGROUND

In the mid-1980s, Apfelberg and colleagues were the first to report their results using the available laser technology on hypertrophic scars and keloids. Their preliminary findings using the argon and CO₂ lasers on keloids were favorable, however, a follow-up publication reported universal scar recurrences in all treated patients.19. Similar initial promising results were also obtained by many other groups, all of whom reported equally disheartening recurrence rates.42, 44, 54, 64, 81

It was not until the early 1990s when the first of a series of studies was published on the successful use of the 585-nm flashlamp pumped pulsed dye laser for hypertrophic scars and keloids. Alster and colleagues reported prolonged improvement in argon laser-induced port-wine stain scars after pulsed dye laser irradiation.11. Clinical assessments and skin surface texture analyses using a computer image analyzer (optical profilometry) revealed that the laser-irradiated scars approximated normal skin characteristics. No scar recurrences were noted 4 years following treatment.6

In 1994, Alster reported clinical and textural improvement in long-standing erythematous and hypertrophic scars. After one or two pulsed dye laser treatments, a 57% to 83% improvement was observed, respectively. Dierickx and colleagues corroborated these favorable findings in 1995, reporting an average scar improvement of 77% after 1.8 laser treatments.53. Not surprisingly, erythematous and hypertrophic facial acne scars were also found to be responsive to 585-nm pulsed dye irradiation in another study published by Alster and McMeekin in 1996.14

Even keloid scars have shown improvement after pulsed dye laser treatments. Alster and Williams irradiated median sternotomy scar halves and compared the clinical, textural, histologic, and symptomatic responses of treated scar halves with the untreated control halves.15. Significant improvement was observed in all clinical parameters within the laser-treated keloids. The histologic finding of increased numbers of regional mast cells after laser irradiation suggests a possible etiologic mechanism for the observed laser effect on scars.

Combining the use of the pulsed dye technology with CO₂ laser vaporization was found to provide an improvement in nonerythematous, minimally hypertrophic scars. Alster and Lewis treated carefully selected scars and performed CO₂ laser de-epithelialization of the scars followed by pulsed dye laser irradiation.12 Significant and prolonged clinical and textural improvement was observed in the treated areas. Goldman and Fitzpatrick have also reported their experience using a combination approach to scar management. They used intralosomal corticosteroids concomitantly with 585-nm pulsed dye laser irradiation in 11 of 37 patients with hypertrophic scars.38. Improvement was observed in all patients, but unfortunately, no distinction was made between those who received laser treatment alone versus those who also received intralosomal corticosteroids. Thus, an adequate evaluation could not be made of the effectiveness of their combined approach.

McDaniel and colleagues have used the same 585-nm pulsed dye laser to effect an improvement in the appearance of striae.38. They observed an improvement not only in skin surface appearance, but also increased dermal elastin after low-fluence laser irradiation. Alster and colleagues also found that low-fluence pulsed dye laser irradiation was superior in the treatment of striae as compared with pulsed dye treatment at regular (scar) fluences and pulsed CO₂ laser vaporization.10. Both groups postulate that the improvement seen may be due to a laser-induced effect on elastin, collagen, or other as yet unknown factors.

CATEGORIZATION OF SCARS AND STRIAE

Because laser technology is expanding so rapidly and its use in the clinical arena con-
continues to evolve, the range of treatment options for scars may prove confusing. In order to determine which laser system or combination of treatments is best for a particular scar or stria, it is imperative to properly identify the type of lesion present.

The fact that it is difficult to quantify and qualify collagen on routine light microscopy makes categorization of scars difficult on histologic grounds alone. Clinical differentiation of scars can also be difficult, especially in the case of hypertrophic scars and keloids, when several clinical features overlap (Table 1). Early and late striae are more easily distinguished both clinically and histologically. Early striae are clinically erythematous, whereas late striae are hypopigmented and fibrotic. The histologic characteristics of early and late striae parallel the clinical features, because dilated capillaries are observed in early erythematous striae and fragmented elastic fibers and epidermal atrophy are seen in later fibrotic lesions.\textsuperscript{83, 85}

**Hypertrophic Scars**

Hypertrophic scars usually develop within the first month following surgery or trauma. They can be located in any area, but the pre-sternal, upper back, and deltoid areas are particularly prone to their development.\textsuperscript{66} They appear as pink, firm, raised bands that are located within the boundaries of the inciting wound.\textsuperscript{77} The prevalence of collagen synthesis and limited collagen lysis during the remodeling phase of wound repair is the probable cause for their formation. Hypertrophic scars may be symptomatic, with pruritus and dysästhesia reported in one third of patients.\textsuperscript{4, 6}

**Keloids**

Keloids appear as red or purple, raised, firm nodules that, unlike hypertrophic scars, grow beyond the margins of the original sites of injury.\textsuperscript{32, 60, 61, 69, 71} They tend to be more invasive of the surrounding normal skin clinically and histologically, with prolongation of the proliferative phase of wound repair. They have thus been described as representations of incomplete tumors.\textsuperscript{72} Although they can occur in any area, they are most commonly seen on the earlobes, shoulders, chest, upper back, and posterior neck. Keloids tend to occur with greater frequency in patients with darker skin tones; however, any patient could potentially develop this exuberant clinical response. Histologic examination typically shows thick bundles of hyalinized collagen arranged in dense swirls or nodules. Despite these characteristic changes, they are not always observed and thus the fine distinction between a hypertrophic scar and keloid is sometimes best made on clinical grounds alone.\textsuperscript{4}

**Striae Distensae**

Striae distensae appear as linear bands of atrophic or wrinkled skin that initially appear erythematous and later hypopigmented. They typically occur in areas that have been excessively stretched, such as that seen on the abdomen, hips, breasts, and around joints (i.e., knees, shoulders) as a result of pregnancy or rapid weight gain or loss.\textsuperscript{85} The pathogenesis of striae has not been fully elucidated, but hormones, particularly estrogen, appear to play a role. In addition, mast cell degranulation with elastolysis may be another etiologic mechanism.\textsuperscript{88} Early striae appear erythema-

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**Table 1. CATEGORIZATION OF SCARS AND STRIAE DISTENSAE**

<table>
<thead>
<tr>
<th>Clinical characteristics</th>
<th>Hypertrophic Scars</th>
<th>Keloid Scars</th>
<th>Striae (Early)</th>
<th>Striae (Late)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Color</strong></td>
<td>White, pink, or red</td>
<td>Deep red or purple</td>
<td>Pink, lavender, purple</td>
<td>White</td>
</tr>
<tr>
<td><strong>Texture</strong></td>
<td>Shiny, minimal markings</td>
<td>Shiny, no markings</td>
<td>Wrinkled</td>
<td>Fibrotic</td>
</tr>
<tr>
<td><strong>Morphology</strong></td>
<td>Raised, firm, within wound borders</td>
<td>Raised, firm, extend beyond wound borders</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Histologic characteristics</strong></td>
<td>Few thick collagen fibers</td>
<td>Thick hyalinized collagen</td>
<td>Dermal inflammation</td>
<td>Epidermal atrophy</td>
</tr>
<tr>
<td></td>
<td>Scanty mucoid matrix</td>
<td>Mucoid matrix</td>
<td>Dilated capillaries</td>
<td>Fragmented elastic fibers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Nodular configuration</td>
<td></td>
<td>Mast cell degranulation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Disorganized arrangement</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

tous and fibrotic, thus clinically and histologically similar to early scars. Late striae, like older scars, are hypopigmented and fibrotic. The clinical and histologic similarities of striae to scars may account for their ability to be treated successfully with pulsed dye lasers.

PREOPERATIVE PATIENT EVALUATION

Patients with scars and striae who desire laser treatment should be evaluated in order to assess whether their particular lesions, skin types, and expectations are amenable to treatment. The use of a checklist (Table 2) is helpful during the initial examination. During the evaluation, it is most important to ascertain what type of scar or stria is present. Whether a scar or stria is erythematous, keloidal, or hypertrophic will determine which laser or lasers are indicated for treatment. Proper categorization of the scar or stria will also permit correct disclosure of information relevant to the laser being chosen, including the number of treatments needed and the anticipated response to each treatment.

The length of time the lesion has been present and its developmental history (ie, when it appeared after surgery or trauma) is also important. Older scars and striae tend to be less erythematous, so an early lesion (<1 year old) that presents for treatment may not necessitate laser intervention, particularly if it is simply erythematous. If, however, hypertrophy is evident within a scar, early intervention has been shown to be helpful in promoting early clinical improvement and decreasing the risk of further worsening. Most hypertrophic scars and keloids show development within the first month following surgery or trauma.

Many patients have received prior treatments to their scars or striae, usually without apparent or significant improvement. Scars that have been treated with cryosurgery, excision, and electrocautery are usually more fibrotic and, thus, even more difficult to treat. Patients should be prepared for the possibility of additional treatments in these circumstances. In contrast, patients who have had silicone or corticosteroid treatment for their scars or striae can undergo laser surgery with the usual and customary tissue response.

Many patients with scars and striae report pruritus or dysesthesia within their lesions, requiring the use of oral antihistamines or pain relievers. These symptoms tend to worsen as they become more erythematous (in the case of striae) or hypertrophic (in the case of scars). The 585-nm flashlamp pumped pulsed dye laser irradiation has been shown to improve the symptoms within one or two laser sessions.

Patients who have a tendency to form keloids will usually show evidence of other similar scars (check the knees, elbows, and hands). Although these patients may not be good candidates for surgical excision or CO2 laser ablation owing to the risk of recurrence or worsening, they can be expected to respond favorably to 585-nm pulsed dye laser irradiation.

Patients with darker skin tones (phototypes IV and greater) have a greater amount of epidermal melanin competing for the 585-nm laser light, thereby reducing the amount of energy effectively delivered to dermal scar tissue. Thus, patients with paler skin phototypes can be expected to obtain greater response following 585-nm laser irradiation.

Patients who expect their scars or striae to disappear after laser treatment will be uniformly disappointed with their results, regardless of the obvious clinical improvement observed in most cases. These patients must be properly informed about the amount of

### Table 2. PREOPERATIVE PATIENT CHECKLIST

<table>
<thead>
<tr>
<th>Scar/striae characteristics</th>
<th>Type</th>
<th>Duration</th>
<th>Etiology</th>
<th>Previous treatment</th>
<th>Symptoms</th>
<th>Predilection</th>
<th>Patient characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>number of months or years</td>
<td>trauma</td>
<td>excision</td>
<td>radiation</td>
<td>pruritus</td>
<td>other sites (list: pregnancy other dermabrasion other)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>erythematous</td>
<td>keloid</td>
<td></td>
<td>surgery</td>
<td>retinoids</td>
<td>silicone</td>
<td>dysesthesia</td>
<td></td>
</tr>
<tr>
<td>hypertrophic</td>
<td></td>
<td></td>
<td>hormones</td>
<td>corticosteroids</td>
<td>pressure therapy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>realistic</td>
<td>unrealistic</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

I | II | III | IV | V | VI
improvement expected in each lesion after treatment and the average number of sessions generally required to effect a significant change. If a patient has unrealistic expectations after proper preoperative education measures have been taken, then that patient should not receive treatment.

LASER PROTOCOL

The number of laser treatments needed to treat scars and striae is dependent on the type of lesion present and each individual’s collagen and wound healing response. In general, two or more laser sessions are needed to treat hypertrophic and keloid scars in order to obtain the desired degree of scar flattening and color lightening (Table 3). As mentioned previously, simple vaporization of hypertrophic scars and keloids produces almost universal scar recurrences and thus should be avoided. Striae distensae, especially the early (erythematous) type, show improvement within one or two treatments (Figs. 1 and 2).

585-nm Flashlamp-Pumped Pulsed Dye Laser

The 585-nm pulsed dye laser is used at average fluences of 6.0 to 7.0 J/cm² with a 5- or 7-mm spot size in the treatment of hypertrophic scars and keloids (Figs. 3 and 4). Striae respond better to lower energy densities (3.0 J/cm²) (Fig. 5). Adjacent, nonoverlapping laser pulses are delivered such that the entire scar or stria is covered. An immediate purpuric tissue response should be produced with a variable amount of reactive hyperemia. Irradiated striae do not typically exhibit purpura owing to the low fluences used, but will usually appear mildly pink after treatment. Scars that do not become purpuric following laser irradiation (this may occur with keloids) can receive additional overlapping or “double” laser pulses. The treated scar or stria is evaluated 4 to 8 weeks postoperatively, at which time another laser treatment at the same or a slightly higher fluence can be delivered, depending on the clinical result obtained. If hyperpigmented laser spots are present within the treated areas, an additional 2 to 4 weeks is given to allow sufficient time for healing before reassessing for further treatment.

Combination Laser Treatment

High-energy, pulsed CO₂ laser de-epithelialization of nonerythematous hypertrophic scars followed immediately by 585-nm pulsed dye laser irradiation has been shown to provide excellent clinical results. The pulsed CO₂ system is not used to effect complete scar vaporization because scar recurrence may result. Rather, one or two passes of the CO₂ laser are performed at 500 mJ energy/pulse and 5 W of power using a 3-mm collimated handpiece to de-epithelialize and produce collagen tightening (or shrinkage) within the scar. A 585-nm pulsed dye laser is then used at an energy density of 6.5 J/cm² to deliver nonoverlapping 5- to 7-mm pulses over the de-epithelialized scar.

There is early evidence suggesting more rapid improvement of keloids and proliferative hypertrophic scars with the simultaneous use of intralesional corticosteroid injections and 585-nm pulsed dye laser irradiation. Patients report immediate cessation of pruritus and rapid flattening of scars after one or two sessions using this combined treatment approach.

POSTOPERATIVE MANAGEMENT

Pulsed dye laser irradiation of hypertrophic scars and keloids produces an immediate purpuric tissue reaction that takes approximately 7 to 10 days to resolve. The skin response of striae distensae to pulsed laser irradiation usually consists of mild tissue hyperemia and edema. When proper fluences

| Table 3. CLINICAL RESPONSE OF SCARS AND STRIAE TO LASER THERAPY |
|------------------|-----------------|-------------------|-------------------|
| Scar Type        | Laser Used      | Number of Treatment Sessions Required | Fluences Used |
| Hypertrophic     | 585-nm pulsed dye | 2–4                         | 6.0–7.0         |
| Keloid           | 585-nm pulsed dye | 2–6                         | 6.0–7.0         |
| Striae           | 585-nm pulsed dye | 1–2                         | 3.0             |
Figure 1. Long-standing hypertrophic surgical scar on the abdomen of a 40-year-old woman before (A) and 2 months after (B) two treatments with a 585-nm flashlamp-pumped pulsed dye laser at an average fluence of 6.5 J/cm² using a 7-mm spot size.

Figure 2. A. Hypertrophic burn scars resulting from a chemical peel 3 years prior, which had been unresponsive to pressure dressings. B. After 3 pulsed dye laser treatments at an average fluence of 6.5 J/cm², scars appeared flatter and less erythematous.

Figure 3. Erythematous acne scars on the cheek of a 30-year-old woman before (A) and 6 weeks after (B) one 585-nm pulsed dye laser treatment at 6.0 J/cm² fluence.

Figure 5. Early (erythematous) striae distensae before (A) and 6 weeks after (B) one pulsed dye laser treatment at 3.0 J/cm² fluence.
and operative technique are used for the type of scar or stria present, vesiculation and crust-ing should not be encountered. During the initial purpuric or erythematosus healing phase, an antibiotic or healing ointment should be applied daily. Showers are permitted, but the lased areas should be gently patted dry. In addition, contact sports during the time the treated skin is at risk for trauma should be avoided. During the secondary healing phase after laser irradiation (lasting 6–8 weeks), care should be taken to prevent sun exposure to the area, because the skin may produce more pigment than normal, making it difficult to identify the degree of improvement achieved. The efficacy of future laser treatment may also be hindered by limiting penetration of the 585-nm laser light through the excessive epidermal pigment into the dermis.

**SUMMARY**

Lasers are now being used successfully to improve various types of scars and striae. It
is not only imperative to properly categorize the type of scars and striae present, but to determine which laser or lasers can best treat them. A 585-nm flashlamp pumped pulsed dye laser is preferred for the treatment of hypertrophic scars, keloids, and striae distensae. CO2 laser vaporization of scars that are proliferative, such as hypertrophic scars and keloids, is not advised due to the high rate of recurrence or worsening. When properly used, lasers can effect the best clinical responses in hypertrophic scars and keloids ever observed. Future laser technologic advances as well as the addition of concomitant lasers or other treatments may enhance clinical results. It appears evident that by promoting the remodeling phase of wound healing, abnormal scarring may be prevented or improved. Laser surgery may best be able to accomplish this by triggering regression of blood vessels and, therefore, fibroblasts within the scar. By so doing, further deposition of connective tissue may be halted.

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