Hypertrophic Scars and Keloids: What Can Lasers Do?

Ivan D. Camacho, MD; Keyvan Nouri, MD

Hypertrophic scars and keloids are prevalent conditions and a common reason for patients to seek medical advice for cosmetic and functional improvement. Multiple modalities of scar revision have been explored in the management of pathologic scars, and studies performed since the mid 1990s have shown evidence of improvement in scar erythema, texture, height, pliability, and associated symptoms using the flashlamp-pumped 585-nm pulsed dye laser. Many authors agree that the most appropriate approach for treating hypertrophic scars and keloids is with the flashlamp-pumped 585-nm pulsed dye laser, which carries a low risk of adverse effects and complications, making it popular for managing pathologic scars. Continued research in and development of laser technology will lead to significant treatment advances in dermatologic laser surgery.

Skin injuries causing scar tissue formation are common and lead many patients to seek treatment for cosmetic and functional improvement.[1] Almost all individuals will undergo 1 or more surgical procedures resulting in scars at some point in their lives. In the United States, more than 70 million surgical procedures are performed annually, with the majority involving skin incisions, encouraging both surgeons and patients to intervene in the scarring process and improve the outcome.[2]

Although research on managing scars has been published, most of it has not been in the form of controlled clinical trials with long-term follow-up, and still there is no universally accepted treatment protocol. Despite the increased knowledge of the biology of wound healing, scar formation remains a therapeutic challenge.

A complex cascade of tissue mechanisms occurs within the skin after epithelial disruption. During the initial inflammatory phase, the complement cascade leads to the release of vasoactive mediators and chemotactic factors that stimulate the migration of inflammatory cells such as macrophages, which play a major role in transitioning to the granulation phase. Then, during the fibroblastic phase, fibroblasts migrate into the area of the injury, producing a new structural framework through deposition of types I and III collagen. Finally, during the maturation phase, all the stimulatory and angiogenic factors decrease, with simultaneous collagen synthesis and degradation that result in flattening of the scar.[3]

Abnormal scarring may result in functional and cosmetic sequelae, including low tensile strength, texture irregularities, pigment alterations, and sensation abnormalities. Severe scarring is more likely to occur if epithelialization takes more than 3 weeks or if tissue tension is produced.[4] Fibroblasts from keloids respond abnormally to stimulation, with a greater capacity to proliferate and produce higher levels of type I collagen, elastin, fibronectin, and proteoglycans, whereas fibroblasts in hypertrophic scars show only a modest increase in collagen. An abnormal balance between proliferation and apoptotic cell death of fibroblasts derived from these pathologic scars may also play a role. Transforming growth factor β appears to be an important cytokine involved in scar formation. It is released by platelets at the injury site and is chemotactic for monocytes and macrophages to begin the production of extracellular

Dr. Camacho is Fellow, and Dr. Nouri is Professor, both at the Department of Dermatology and Cutaneous Surgery, University of Miami, Miller School of Medicine, Florida.

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matrix proteins. It also increases the expression of types I and III procollagen. Platelet-derived growth factor, insulin-like growth factor, and abnormal levels of several cytokines, including interleukins 6, 13, and 15, have also been implicated in the formation of pathologic scars.[5,6]

CLASSIFICATION OF SCARS

Hypertrophic scars and keloids are the most prevalent types of pathologic scars that may present after a cutaneous insult. Adequate classification of scars is imperative before any treatment is initiated. Other types of scars, such as striae distensae, atrophic scars, and pigmented scars, will not be discussed in this article.

Hypertrophic scars and keloids affect millions of patients, with an overall incidence of 4.5% to 16% in the general population.[7] Hypertrophic scars are abnormal tissue proliferations that usually develop within a month of injury and may take up to 2 years to mature. The growth of these scars is limited to the area of epithelial disruption and is characterized by thickened, hyalinized collagen bundles arranged in nodular proliferation with interspersed, immature fibroblasts and increased amounts of extracellular matrix, elastin, and proteoglycans. Hypertrophic scars usually present as firm, raised nodular growths that commonly involve areas of slow wound healing and areas subject to pressure or movement. Patients with hypertrophic scars may complain of pruritus and dysesthesias. Hypertrophic scars may spontaneously involute and usually do not recur if successfully treated.[5,8]

Keloids, in contrast, proliferate beyond the margins of the initial skin insult and often continue to grow over time. They are characterized by thickened bundles of hyalinized, acellular collagen haphazardly arranged in whorls or nodules, with increased hyaluronidase, eosinophils, mast cells, plasma cells, and lymphocytes. Keloids present as red-purple papules or nodules that are often cosmetically disfiguring and tend to occur in areas such as the earlobes, cheeks, anterior chest, shoulders, and upper back. Keloids may also present with pruritus and dysesthesias, as well as tenderness, motion restriction, ulceration, and secondary infections. They are more common in dark-skinned individuals, with incidence 5 to 15 times greater than that seen in light-skinned individuals. Keloids may develop weeks and even years after the initial insult. Complete resolution of keloids is difficult and the recurrence rate is high, even after adequate treatment.[9,10]

NONLASER APPROACHES TO HYPERTROPHIC SCARS AND KELOIDS

Different methods of scar revision, with varying degrees of success, have been explored in the treatment of hypertrophic scars and keloids.

Surgical Excision

Surgical excision of keloids is usually followed by recurrence unless adjunct treatment is implemented. Despite different surgical excision techniques (fusiform, intramarginal, W-plasty, and Z-plasty), the recurrence rates reported with surgery alone range from 45% to 100%. An important consideration is to perform scar revision without tension.[11,12]

Radiation

Radiation treatment is usually administered with surgical excision, with a combined recurrence rate of 10% to 20%. The response to radiation is dose related; the recommended dose is 1500 Gy, delivered in fractions within 10 days of surgery. The proposed mechanism of action is the inhibition of fibroblast proliferation and angiogenesis during the healing process. Case reports have described the development of secondary neoplasms and chronic radiodermatitis.[13,14]

Silicone and Occlusion

Significant scar softening has been shown after application of topical silicone gel sheeting or cushions for 12 or more hours daily for 2 to 4 months. Increased hydration with occlusion affects collagen synthesis. Despite being a safe treatment, some adverse effects of occlusion include contact dermatitis and heat rash.[15-17]

Pressure

Continuous scar pressure (24–40 mm Hg) produces tissue ischemia, decreasing tissue metabolism and increasing collagenase activity. Some studies have proposed that pressure induces the release of metalloproteinase 9 and prostaglandin E_2 with subsequent extracellular matrix remodeling and scar softening. A pressure dressing must be worn for at least 18 hours daily for no less than 6 months to achieve results, making patient compliance the greatest obstacle to successful treatment using this modality.[18,19]

Cryotherapy

Cryotherapy is used as monotherapy or in combination with other modalities. Freezing induces vascular damage and circulatory stasis, leading to anoxia and eventual necrosis. Usually the entire scar is treated with 2 or 3 freeze-thaw cycles of 30 seconds each. Facial scars and scars older than 12 months respond the least. Some adverse effects are hypopigmentation (often permanent) in dark-skinned patients, delayed healing, pain, and atrophy.[4,20,21]

Intralesional Corticosteroids

Intralesional corticosteroids are used as monotherapy or in combination with surgical excision and cryotherapy.

Intralesional corticosteroids suppress collagen synthesis by downregulation of the collagen gene expression. Their use is limited because of poor penetration to the deep dermis; they work best in young hypertrophic scars. The most commonly used corticosteroid is triamcinolone acetonide 10 to 40 mg/mL intralesionally. Adverse effects include pain from injection, atrophy, telangiectasias, necrosis, ulcers, and, most troubling in dark-skinned patients, hypopigmentation that may last more than 1 year.[11,22]

Intralesional 5-Fluorouracil

Thymidylate synthase is inhibited by 5-fluorouracil (5-FU), which therefore inhibits cell division and fibroblast proliferation. Intralesional injections of 5-FU 2 to 50 mg 3 times per week showed improvement in most patients treated, with a better response in young scars. The addition of pulsed dye laser (PDL) treatments with 5-FU injections showed more effectiveness than 5-FU alone. Adverse effects include pain from injection, purpura, and superficial sloughing.[23]

Intralesional Interferons

Intralesional interferons (IFNs) reduce scar height by decreasing the production of types I and III collagen. Use of IFN alfa-2b after keloid removal showed an 18.7% recurrence rate compared to 58.4% with triamcinolone acetonide. Adverse effects include pain with injection and flulike symptoms.[24]

Imiquimod

Imiquimod induces local IFNs at the application site and downregulates collagen synthesis. A study by Berman and Kaufman[25] reported no recurrence of keloids 24 weeks postexcision with the topical application of imiquimod initiated the day of excision. Adverse effects include hyperpigmentation, erythema, irritation, and erosions.

LASER APPROACH TO HYPERTROPHIC SCARS AND KELOIDS

Cutaneous laser surgery was transformed in the 1980s with the introduction of the selective photothermolysis theory by Anderson and Parish, in which controlled destruction of a target lesion is possible without significant thermal damage to the surrounding normal tissue.[26]

The use of early-generation continuous-wave argon, carbon dioxide, and Nd:YAG lasers is limited by their high incidence of scar recurrence and other adverse effects, including pain, skin atrophy, and dyspigmentation.[1,27] In contrast, research studies since the mid 1990s have shown evidence of improvement in scar erythema, texture, height, pliability, and associated symptoms using the flashlamp-pumped 585-nm PDL for treating both hypertrophic scars and keloids, with low recurrence rates and a low adverse-effect profile.[28-31]

Several theories have been proposed on the mechanisms by which the flashlamp-pumped 585-nm PDL achieves clinical effects. Laser-induced tissue hypoxia promotes a catabolic state of decreased cellular function, and laser-induced collagen heating disrupts disulfide bonds, resulting in reorganization and realignment of collagen fibrils. Irradiation with flashlamp-pumped 585-nm PDL may also affect collagen remodeling through cytokine stimulation and reduce extracellular matrix expression by reducing transforming growth factor β1.[3,32,33]

Individual factors should be considered when assessing patients for laser scar revision. The pulse duration and the fluence, or energy, density (measured in joules per squared centimeter) are determined by the type of scar to be treated, the skin phototype of the patient, and previous treatments applied to the area. Dark-skinned patients are at increased risk for dyspigmentation; fluences should be lowered by at least 0.5 J/cm^2, necessitating more treatment sessions to obtain results. Scars that have received previous treatments tend to present with increased fibrosis; they are more difficult to treat with lasers and require higher fluences and more treatment sessions. Fluences should be lowered for scars in more delicate or thin-skinned locations, such as the anterior chest and neck.[34,35]

In general, hypertrophic scars and keloids are treated with fluences ranging 6.0 to 7.5 J/cm^2 when using a spot size of 5 to 7 mm and 4.5 to 5.5 J/cm^2 when using a spot size of 10 mm; however, better results tend to occur with lower fluences and multiple treatment sessions.[35] Lower fluences should be applied at initial treatment sessions, with upward adjustments as necessary. If postoperative crusting, oozing, or vesiculation occurs, the fluence must be decreased and treatment should be postponed until the skin has completely healed.[1] Although early intervention is generally recommended in patients known to be susceptible to scars, active infectious or inflammatory conditions should be treated and either controlled or resolved before attempting laser treatment.[36]

Several studies have shown the efficacy of the flashlamp-pumped 585-nm PDL in treating hypertrophic scars and keloids.[8,37,38] Based on the principle of selective photothermolysis, the flashlamp-pumped 585-nm PDL specifically targets blood vessels within the scar tissue without damaging the surrounding normal tissue. The use of the flashlamp-pumped 585-nm PDL has shown significant reduction of scar erythema, height, pliability, surface texture, and associated symptoms, as well as histologic evidence of decreased sclerosis in patients with hypertrophic scars and keloids. Minimal discomfort and a low adverse-effect profile make the flashlamp-pumped 585-nm PDL

a popular therapeutic approach for pathologic scars.[8,37,38] Facial scarring in patients with acne excoriée was also reported to improve with the flashlamp-pumped 585-nm PDL when combined with psychodynamic therapy.[39]

The optimal time to begin laser treatment after cutaneous insult or keloid removal to improve appearance and prevent the formation or recurrence of pathologic scars has not yet been established. Some authors have reported the safety, efficacy, and benefit in the early use of flashlamp-pumped 585-nm PDL in surgical scars, starting the day of suture removal. Pigmentation, vascularity, pliability, and height, as well as cosmetic appearance, were assessed, and significant improvement was demonstrated compared to the non-treated control areas.[40,41] Comparable results in scar assessment were achieved with the use of the cryogen-cooled 595-nm PDL starting the day of suture removal.[42]

The most common adverse effects reported with the flashlamp-pumped 585-nm PDL are immediate swelling of the treated skin, which usually subsides in 48 hours, transient dyspigmentation, which usually resolves after a few weeks, and postoperative purpura, which may persist for 7 to 10 days.[43] Most hypertrophic scars improve by at least 50% after 2 treatments with the flashlamp-pumped 585-nm PDL treatments, whereas keloids often require additional sessions with the flashlamp-pumped 585-nm PDL to achieve significant clinical improvement. Treatment-delivery intervals of 6 to 8 weeks are recommended to allow adequate healing. Single treatments with the flashlamp-pumped 585-nm PDL at the time of suture removal have not provided significant benefits to cosmetic appearance.[44]

SUMMARY

Scar tissue formation is a prevalent condition and a common reason for patients to seek treatment for cosmetic and functional improvement. Despite increased knowledge of the biology of wound healing and scar formation, pathologic scars remain a therapeutic challenge.

Multiple modalities of scar revision, with varying degrees of success, are used for treating hypertrophic scars and keloids. Research studies during the past decade have shown evidence of improvement in scar erythema, texture, height, pliability, and associated symptoms of these pathologic scars using the flashlamp-pumped 585-nm PDL, and most authors agree that this laser system is currently the most appropriate for treating hypertrophic scars and keloids, with minimal discomfort and low risk of adverse effects and complications.

Vascular-specific laser systems, such as the flashlamp-pumped 585-nm PDL and the cryogen-cooled 595-nm PDL, have shown efficacy in improving the texture and appearance of surgical scars when started the day of suture removal.

Continued research in laser technology will lead to significant treatment advances in dermatologic laser surgery. Additional prospective, well-controlled clinical studies are warranted to determine the long-term efficacy and safety of several therapeutic approaches in dermatologic laser surgery for patients with hypertrophic scars and keloids.

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