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Treatment of keloids and hypertrophic scars with the triple-mode Er:YAG laser: A pilot study

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Abstract

Introduction: Hypertrophic scars and keloid formation are common problems which are not only the result of surgical procedures. Many treatment protocols exist without standardization. The aim of our study was to compare various treatment protocols using a 2940 nm Er:YAG laser with and without additional silicone gel application.

Patients and methods: Twenty-one patients suffering from keloids or hypertrophic scars were treated in four groups with the Burane XL Er:YAG laser (Quantel Derma GmbH; Erlangen, Germany) either in thermal or combined thermoablative mode with or without additional silicone gel application under non-blinded conditions. The appearance of the scars (redness, hardness and elevation) before therapy, and 12 months after therapy was evaluated by therapists based on a scaling system from 0 to 3 (0 = minimum, 3 = maximum).

Results: The patient group was made up of 21 people, 16 females and five males, ranging in age from 16 to 79 years. All patients had a mean reduction of redness, hardness and scar elevation by 51.3% ($p = 0.0012$), 48.9% ($p = 0.0015$) and 50.0% ($p = 0.0015$), respectively. There was no significant difference between groups with or without additional silicone gel application ($p > 0.05$).

Conclusion: Our pilot study proved the effectiveness of Er:YAG laser treatments (thermal and combined thermoablative mode) for the reduction of hypertrophic scars and keloids. However, the additional application of silicone gel was not as effective as postulated. Larger randomized double-blinded studies are needed to further evaluate treatment protocols for hypertrophic scars and keloids.

Keywords: Keloid; Hypertrophic scar; Er:YAG; Laser; Silicone gel sheeting

Introduction

Pathological hypertrophic scars and keloid formation have a considerable effect on the functional and esthetic results of wound healing after accidents and surgical interventions. The underlying pathology of this complication is still unknown [1]. Generally, wound healing of the skin results in defect repair with scarring [2]. Hypertrophic scars are confined to the original wound site, whereas keloids are characterized by an overgrowth of scar tissue exceeding the borders of the original wound area [3]. Several treatment modalities, such as topical silicone gel sheeting, intralesional injections of various agents (e.g. corticosteroids, α or γ interferon, 5-fluorouracil), positive pressure dressings, cryotherapy, surgical removal, and laser therapy are in use but are not all completely successful [4–6]. Our experience revealed that a combination of these therapies may be the key to an effective outcome.

Scar laser treatments were first published in the 1980s with the continuous wave carbon dioxide (CO_2), argon

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and neodymium-doped yttrium aluminum garnet (Nd:YAG) laser. These therapies led to a recurrence or a worsening of the scarring. In the 1990s, high-energy pulsed CO_2 and erbium:YAG (Er:YAG) lasers improved the therapeutic options by causing less side effects with a wide range of indications [7,8]. The short-pulsed Er:YAG laser was designed as a less aggressive alternative to CO_2 lasers. The Er:YAG laser emits a wavelength of 2940 nm. This wavelength relates to the peak absorption coefficient of water and is absorbed 12–18 times more efficiently by cutaneous tissue than the CO_2 laser (10,600 nm) [9]. With a pulse duration of 250 μs, the short-pulsed Er:YAG laser removes 10–20 μm of tissue per pass at a fluence of 5 J/cm^2, resulting in a residual zone of thermal injury not exceeding 15 μm [10,11]. To overcome the limitations of short-pulsed Er:YAG lasers, long-pulsed systems (so-called "modulated", "dual-mode" or novel "triple-mode" Er:YAG lasers) have been developed which combine ablative and coagulative pulses to produce deeper tissue vaporization, greater contraction of collagen, and improved hemostasis [11].

With subablative pulses of up to 500 μs, Er:YAG-laser systems can produce larger zones of residual thermal injury reaching the dermal compartment of the skin [12]. Supraphysiologic temperatures induce a heat shock response (HSR) that results in temporary changes in cellular metabolism. The result of this HSR is the production of proteins known as heat shock proteins (HSP). HSP 70 is produced following laser application and plays an important role of coordination of growth-factor expression such as transforming growth factor beta (TGF-β). TGF-β is prominent in the inflammatory response and fibrogenic process [13]. Combined treatment with CO_2 and Er:YAG lasers suppresses the production of TGF-β1 in keloid-producing fibroblasts [14]. Nd:YAG-laser radiation decreases collagen production without affecting cell proliferation [15]. The thermal modus of Er:YAG laser systems induce collagen neogenesis and dermal collagen formation by thermal injury. Histologically, these new collagens replace the elastotic collagen of connective tissues, leading to a decrease in the clumping of collagen bundles and an increase of thin collagen fibers with regular orientation in the upper dermis. A rise of procollagen expression in dermal fibroblasts to a depth of about 320 μm is found by immunohistochemistry [16]. Despite these findings, the complete mechanism is not yet fully understood.

Silicone-based products are widely used in the treatment of hypertrophic scars and keloids; this management is described in numerous evidence-based publications as being effective for the prevention and treatment of hypertrophic scars [6,17–21].

The present study was a clinical pilot trial with four groups of patients ($n = 21$) with keloids and hypertrophic scars who received treatments with Er:YAG laser (thermal mode versus combined thermoablative mode), with or without additional silicone sheeting. The purpose of this clinical study was to evaluate the efficacy of these treatment variations.

Materials and methods

Patients

Twenty-one patients with keloids and hypertrophic scars were treated with a 2940 nm Er:YAG laser (Burane XL; Quantel Derma GmbH, Erlangen, Germany) and silicone gel sheeting (Dermatix, now sold as Kelo-cote®; ABT Deutschland GmbH, Arnsberg, Germany) under non-blinded conditions after informed consent. The patient group was made up of 16 females and 5 males, ranging in age from 16 to 79 years old. All scars had existed more than one year; there had been no previous laser treatment. The scars were located at different locations on the face and body.

The patient pool was split into four treatment groups as follows.

- Group #1: thermal mode without silicone gel application
- Group #2: thermal mode with silicone gel application once daily
- Group #3: combined thermoablative mode without silicone gel application
- Group #4: combined thermoablative mode with silicone gel application once daily

Patients were allocated to the four groups in the order that they appeared in our outpatient department.

Laser

The used Burane XL laser is a so-called "triple-mode" Er:YAG laser which can be operated in an (1) ablative, (2) thermal or (3) combined thermoablative mode. The Er:YAG laser with 2940 nm achieves the highest absorption in water. Consequently, the laser energy causes immediate vaporization of the tissue water in the upper skin layers and therefore ablates thin layers. The thermal load on the tissue beneath this layer is very low, leading to the term "cold ablation" (ablative mode). When the triple-mode Er:YAG laser is run in the thermal mode, a sequence of subablative pulses brings thermal energy to the skin allowing thermal stimulation of the dermis. The "combination mode" is characterized by a cold superficial ablation followed by subablative pulses.

Procedure

All patients were treated with a 5-mm spot using a 30% overlap technique. Every patient received about six laser sessions with a four-week interval. The following thermal energy fluences were chosen: 3.0 J/cm^2 (first treatment session), 3.3 J/cm^2 (second treatment session), 3.5 J/cm^2 (third treatment session), 4.0 J/cm^2 (fourth, fifth and sixth treatment session). For patients treated with the combined mode, additional ablative energy was chosen at 1.0–3.0 J/cm^2 depending on the thickness of the scar.