Fractional CO_2 laser for the treatment of acne scars

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Summary

Background Numerous reports have been published on skin rejuvenation by the so-called fractional laser device that delivers a laser beam in a dot form over a grid pattern.
Aims In this study, we characterized the effects of a fractional CO_2 laser on atrophic acne scars at the clinical and ultrastructural levels.
Methods Seven healthy adult Japanese volunteers (aged 32–46 years, mean 37.6, five men and two women of Fitzpatrick skin type III) were recruited for this study. A fractional CO_2 laser device, SmartXide DOT (DEKA, Florence, Italy), was used with irradiation parameters set as follows: output power 10 W, pulse width 600 μs, dot spacing 800 μm, and stack 2 (irradiation output power 0.91 J/cm^2). A clinical examination and punch biopsy of each subject was performed before and just after the irradiation, and also at week 3 after three irradiation sessions. The biopsy specimens were stained with toluidine blue and were examined ultrastructurally.
Results Clinical improvement of the atrophic acne scars was observed at week 3 after the third irradiation session in all cases compared with the condition before treatment. Histologically, outgrowths of many degenerated elastic fibers were observed as irregular rod-shaped masses in the superficial dermis prior to the treatment in the region of the acne scars. At week 3 after the third irradiation, the degenerated elastic fibers were no longer observed, and the elastic fibers were elaunin-like.
Conclusions The fractional CO_2 laser is considered to be very effective for treating atrophic acne scars.

Keywords: rejuvenation, fractional CO_2 laser, ultrastructural study, acne scar, histology

Introduction

Many approaches to rejuvenate the skin in an effort to improve its appearance, including reduction of wrinkles and pigmentation, have been developed. Those include cosmeceuticals[1] (such as retinol and kinetin), chemical peeling[2] (with glycolic acid or lactate acid), nonablative photorejuvenation[3–5] (with pulsed dye lasers, KTP lasers, and IPL-type near-infrared red light–emitting devices), and ablative laser therapy[6,7] (using CO_2 and Er:YAG lasers).

However, the effects of cosmeceuticals and chemical peeling methods are limited, and patients are often dissatisfied with the effects of nonablative photorejuvenation, because of the lack of any dramatic clinical change. IPL-type therapy, which is widely used and is very popular in Japan, because of the short downtime

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and the marked effects on pigmented lesions, has little effect on the dermis and often needs to be combined with other therapies. Ablative laser therapy is considered to be the gold standard for the so-called rejuvenation of the skin because it stimulates new collagen formation and has dramatic effects. However, as the removal of all epithelial layers causes great heat damage to the dermis and the epithelial regeneration takes time, sufficient postoperative care is needed, and the wound healing takes at least 2 weeks. Furthermore, repigmentation and scar formation occur at a high frequency, and keloid formation occasionally occurs in Oriental populations, including Japanese; thus, this therapy is not often employed in Japan.

The so-called fractional laser device that delivers the laser beam in a dot form over a grid pattern has been developed with several wavelengths.[8–10] When this fractional laser device is employed using a CO_2 laser, as normal skin remains around the dot-pattern laser-irradiated area, this method has the merits of a rapid epithelial regeneration and a short downtime. Numerous reports about the actual clinical effects of the fractional laser have been published.

Acne scars[11] can be divided into atrophic and proliferative types. Collagen degeneration extending to the dermis occurs in atrophic acne scars, although the precise mechanism underlying their formation remains unknown. In addition, atrophic scars are difficult to cure clinically compared to other types of traumatic scars. In this study, we employed a fractional CO_2 laser to treat atrophic acne scars, and we verified the effects of the treatment both clinically and ultrastructurally.

Materials and methods

Subjects

Seven healthy adult Japanese volunteers (aged 32–46 years, mean 37.6, five men and two women of Fitzpatrick skin type III) were recruited for this study. Subjects with chronic illness, atopic dermatitis, contact dermatitis, photosensitivity, a history of scarring or poor wound healing, vascular disease, or cutaneous disease were excluded. Written informed consent was obtained from each volunteer, and the study was approved by the Ethics Committee of the Queen's Square Medical Center.

Methods

A fractional CO_2 laser device, SmartXide DOT (DEKA), was used for this study. This device generates two-step peak pulses (SmartPulse system): the pulse waveform with the high peak power vaporizes the epidermis and the upper layers of the dermis in the first step and the pulse waveform with the long pulse width then radiates heat around the vaporized and coagulated area, which produces thermal effects in the deep dermal tissues (Fig. 1). After the removal of any cosmetic makeup and washing, the face of each subject was irradiated. All irradiations were performed using the same settings: output power 10 W, pulse width 600 μs, dot spacing 800 μm, and stack 2 (irradiation output power 0.91 J/cm^2). A 1.5-cm square was irradiated by a single pass in the scanning mode. After the irradiation, the treated area was sufficiently cooled and a fusidic acid antibiotic was applied for 3 days.

Before treatment, each subject's face was washed, and photographs of the front, right, and left sides of each face

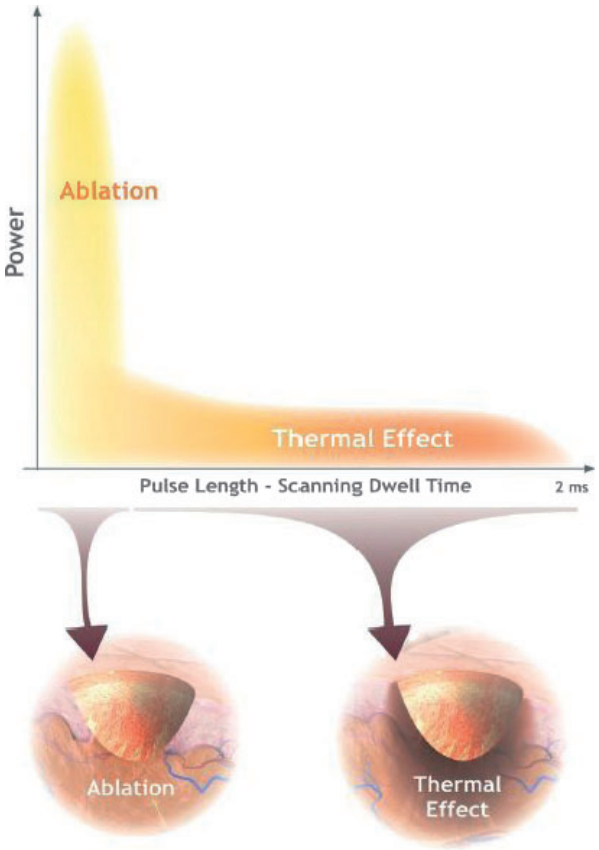

Figure 1 A fractional CO_2 laser device, SmartXide Dot (DEKA), was used for this study. This device generates two-step peak pulses (SmartPulse system): the pulse waveform with the high peak power vaporizes the epidermis and the upper layers of the dermis in the first step and the pulse waveform with the long pulse width then radiates heat around the vaporized and coagulated area, which produces thermal effects in the deep dermal tissues.

were taken. Photographs were also taken prior to and after each of the three treatment sessions and once after the last session, yielding a total of four sets of photographs. In addition, 3-mm punch biopsies were obtained before and just after each irradiation session and also at week 3 after the third irradiation session.

Each specimen was fixed in glutaraldehyde (2.5%) and later in osmium tetroxide (1%). After dehydration through a graded ethanol series, the specimens were embedded in Epon 812 (Oken Shoji Co., Ltd, Tokyo, Japan), stained with toluidine blue, and examined by light microscopy. Ultrathin sections were obtained with an Ultracut N ultramicrotome (Reihert-Nissei, Tokyo, Japan) and a diamond knife. Sections were stained with oolong tea extract (OTE) for connective tissue,[12] uranyl acetate, and lead citrate prior to electron microscopic examination (75 kV, Hitachi H-7500; Hitachi, Tokyo, Japan).

Results

Clinical findings

Figure 2 shows the morphology prior to irradiation. Grayish crust-like dots in a point grid pattern were observed immediately after the irradiation (Fig. 3) in all seven subjects. The dots were slightly erythematous from immediately after to about 1 day after the irradiation and had disappeared by 3–7 days. This response was observed after each of the three irradiation sessions.

Figure 2 The morphology prior to irradiation. Moderate pitted acne scars were observed specially on the both cheek.

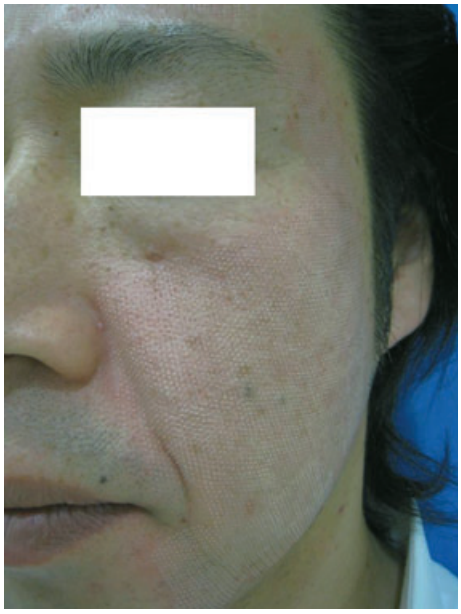

Figure 3 Grayish crust-like dots in a point grid pattern were observed immediately after the irradiation in all seven subjects. The dots were slightly erythematous from immediately after to about 1 day after the irradiation.

Improvement in the atrophic acne scars, compared with the condition before treatment, was observed at week 3 after the three irradiation sessions (Fig. 4). No adverse events were noted in any of the subjects, except for the slight erythema described earlier.

Histological findings

As the histological findings were almost similar in all seven subjects, time-dependent changes are described below, without specifying the subjects.

Light microscopic observations after toluidine blue staining
Immediately after each irradiation session, degeneration and desquamation of the epithelium and bleeding were observed in the irradiated area (arrow) (Fig. 5a). An enlarged image (Fig. 5b) shows that the irradiated area was 150–180 μm in diameter, the epithelium was desquamated, and the dermis was exposed. At week 3 after the third irradiation session, almost complete regeneration of the epithelium was noted.

Ultrastructural findings in the acne scar epithelium
Prior to the treatment, no significant lesions were found in the epithelium. Immediately after each irradiation session, degeneration and desquamation of the epithelium was noted, and the basal lamina remained intact.

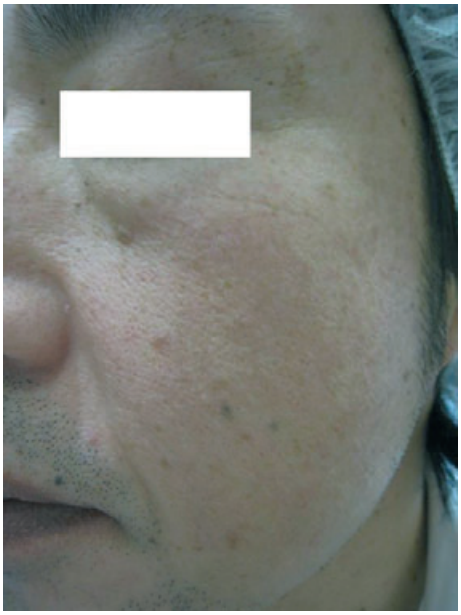

Figure 4 Improvement in the atrophic acne scars, compared with the condition before treatment, was observed at week 3 after the three irradiation sessions. No adverse events were noted in any of the subjects, except for the slight erythema described earlier.

In addition, bleeding was seen between the stratum corneum and stratum granulosum in the desquamated epithelium (Fig. 6a). At week 3 after the third irradiation session, complete regeneration of the epithelium was observed in the area of degeneration and desquamation (Fig. 6b). Epithelial cells undergoing mitosis (arrow) were also often observed.

Ultrastructural findings in the superficial dermis in the region of the acne scars

Prior to the treatment, numerous outgrowths of elastic fibers were observed in the superficial dermis in the region of the acne scars. Examination of the specimens stained with OTE revealed the presence of elastin in the elastic fibers as electron-dense spherical or rod-shaped masses (Fig. 7a). Immediately after each irradiation, the localized disappearance of the elastin in the elastic fibers (arrows) was often observed (Fig. 7b). At week 3 after the third irradiation session, elastin was observed as electron-dense deposits, but the elastic fibers (arrows) as a whole were fragmented, showing a elaunin-like appearance (Fig. 7c).

Discussion

Histologically, in the late stages, acne inflammation is mainly composed of lymphocytes and histiocytes, and some lesions show foreign-body granuloma-like features

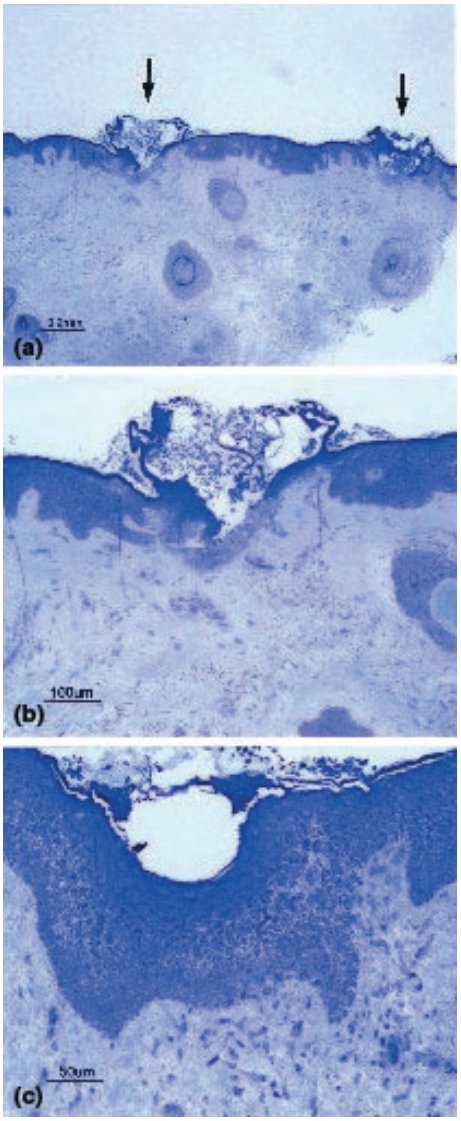

Figure 5 Light microscopic observations after toluidine blue staining. Immediately after each irradiation session, degeneration and desquamation of the epithelium and bleeding were observed in the irradiated area (arrow) (a). An enlarged image (b) shows that the irradiated area was 150–180 μm in diameter, the epithelium was desquamated, and the dermis was exposed. At week 3 after the three irradiation sessions, almost complete regeneration of the epithelium was noted (c).

containing giant cells. This inflammatory cell infiltration disappears within about 2 days, clinically resulting in erythematous lesions alone, but they occasionally progress to develop into acne scars. The mechanisms underlying acne scar formation are largely unknown; however, acne scars are roughly divided into atrophic scars, including the so-called ice-pick-type and macular-type scars, and hypertrophic/proliferative scars, e.g.,

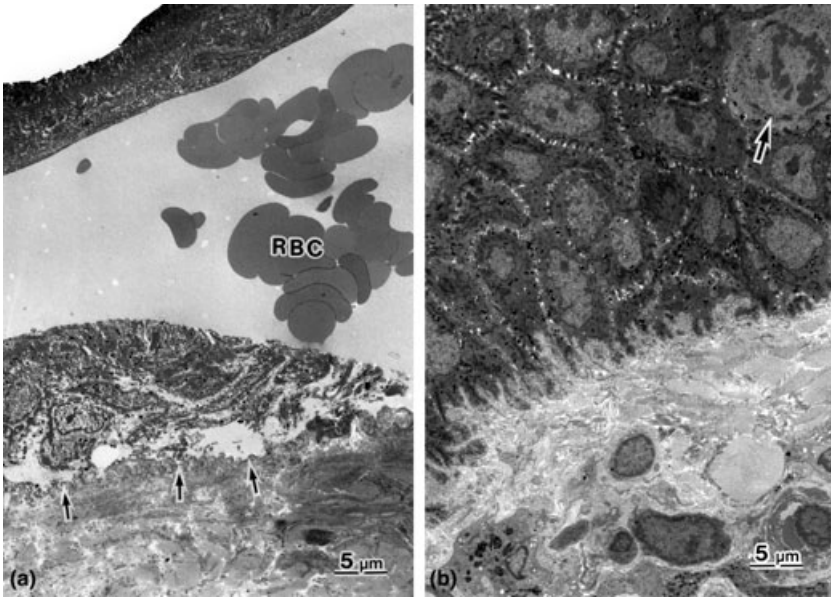

Figure 6 Ultrastructural findings in the acne scar epithelium. Prior to the treatment, no significant lesions were found in the epithelium. Immediately after each irradiation session, degeneration and desquamation of the epithelium was noted, and the basal lamina remained intact. In addition, bleeding was seen between the stratum corneum and stratum granulosum in the desquamated epithelium (a). At week 3 after the three irradiation sessions, complete regeneration of the epithelium was observed in the area of degeneration and desquamation (b). Epithelial cells undergoing mitosis (arrow) were also often observed.

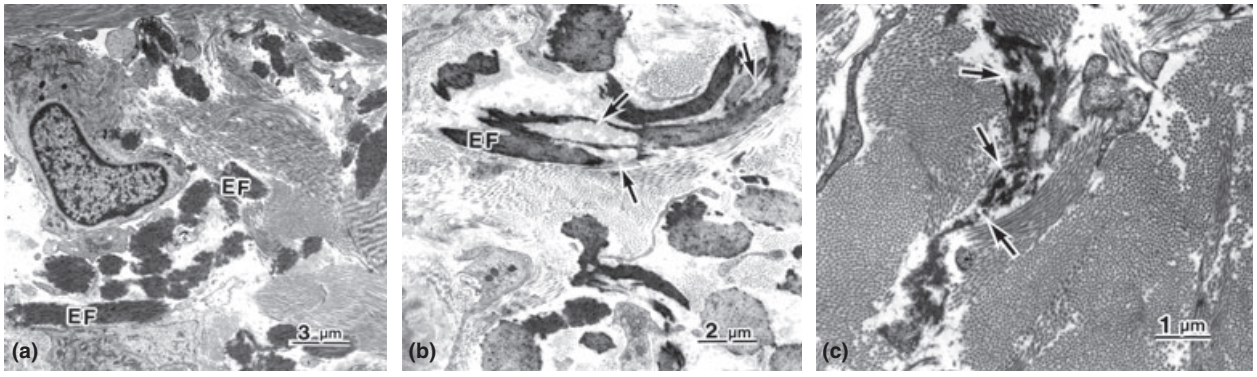

Figure 7 Ultrastructural findings in the superficial dermis in the region of the acne scars. Prior to the treatment, numerous outgrowths of elastic fibers were observed in the superficial dermis in the region of the acne scars. Examination of the specimens stained with OTE revealed the presence of elastin in the elastic fibers as electron-dense spherical or rod-shaped masses (a). Immediately after each irradiation, the localized disappearance of the elastin in the elastic fibers (arrows) was often observed (b). At week 3 after the three irradiation sessions, elastin was observed as electron-dense deposits, but the elastic fibers (arrows) as a whole were fragmented, showing a elaunin-like appearance (c).

keloids. Most scars heal within a few months, although acne scars can persist for many years. Morphological abnormalities of the collagen fibers are believed to be involved in the development of such persistent atrophic acne scars.[11,13,14]

In the ultrastructural investigation of this study, numerous outgrowths of elastic fibers were observed in the superficial dermis in the region of the acne scar prior to the treatment. After treatment, degeneration of the elastin in the elastic fibers was observed, with electron-dense spherical or oval irregular masses in the rod form being observed after connective tissue staining (OTE staining) of the sections. Acne scars show a clinically solid aspect, a finding consistent with the outgrowth of degenerated elastic fibers. Thus, it is difficult to treat atrophic acne scars that show

degeneration of collagen fibers, although the effectiveness of treatment with resurfacing and fractional lasers has been reported.

In this study, we used a fractional CO_2 laser to treat atrophic acne scars, which are considered to lend themselves well to examination of changes occurring in the dermis during the rejuvenation treatment, and we conducted an ultrastructural investigation.

The fractional CO_2 laser device used in this study, SmartXide DOT (DEKA),[15] delivers a laser beam in a punctate pattern (spot size 0.12 mm), vaporizes the epidermis and part of the dermis, and at the same time, promotes collagen contraction via its thermal effects, thereby inducing skin remodeling. The irradiation fluence (J/cm^2) is determined by a combination of three parameters, power (output), dwell time (pulse width), and dot pitch (distance between irradiation points).

This device delivers two-step peak pulses (SmartPulse system), which produces balanced vaporization, coagulation, and thermal effects on the tissues. The pulse waveform with the high peak power emitted in the first step vaporizes the epidermis and superficial layers of the dermis, and the pulse waveform with the long pulse width emitted in the next step radiates heat around the vaporized and coagulated area, exerting thermal effects on the deeper dermal tissues. These effects cause collagen contraction, producing a skin-tightening effect that is considered to be effective for the treatment of acne scars.

In addition, the continuous emission mode (stack mode) used by this device allows irradiation of the same spot up to five times, enabling it to affect the deeper dermis. As compared to the emission of an increased amount of energy in one emission, the fractional emission of the same amount of energy is considered to be associated with a reduced risk of erythema and pigmentation posed by excess thermal energy on the epidermis.

There are numerous reports on the clinical usefulness of resurfacing the skin with fractional lasers.[8–10] In this study, the desquamation of the epithelium and the exposure and degeneration of the upper layer of the dermis were confirmed immediately after each irradiation, in accordance with the interval of the fractional laser irradiation. This was consistent with the ablation mechanism of the device used in this study being similar to that of the CO_2 laser, as reported previously. Ultrastructurally, the degeneration of the epithelium leaving the basal lamina intact in the irradiated area appeared to cause the epithelial regeneration to occur more rapidly after irradiation with this laser than with an ablation-type laser, as is the case after thermal injury in which the epithelium with the basal lamina regenerates more rapidly.

Evidence of regeneration of the epithelium at week 3 after the three irradiation sessions was observed by light microscopy and by electron microscopy in this study. Clinically, the formation of crust-like dots was observed after each irradiation session. In addition, the satisfactory and complete regeneration of the epithelium was observed at week 3 after treatment completion. These observations lend support to the suggestion based on clinical observations that laser treatment sessions should be undertaken at intervals of week 3 to 1 month.

Disappearance of elastin was observed in the dermis immediately after irradiation, and elaunin-like elastin fibers were subsequently observed at week 3 after the three irradiation sessions. During the normal rejuvenation process, immature elastic fibers, i.e., elaunin fibers, are observed in the dermis, and remodeling of the dermis is considered to occur at the same time.[4,16,17] Based on this knowledge, the elaunin-like elastic fibers observed in this study are considered to reflect dermal remodeling. The proliferation of degenerated elastic fibers poses a significant clinical problem, particularly in acne scars, as described earlier. In this study, the disappearance of existing elastic fibers and outgrowths of elaunin fibers were seen immediately after the irradiation treatment. Therefore, we conclude that the fractional CO_2 laser used in this study is very effective for the treatment of acne scars, even from a histological standpoint.

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