Efficacy of Light-Emitting Diode Photomodulation in Reducing Erythema After Fractional Carbon Dioxide Laser Resurfacing: A Pilot Study

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BACKGROUND The most common side effects of fractional carbon dioxide (CO_2) laser resurfacing are erythema and edema of the treated skin. Light-emitting diode (LED) devices have been shown to stimulate fibroblast activity and hasten wound healing. The current study was designed to evaluate the efficacy of such LED devices in treating post-laser therapy erythema.

OBJECTIVES To evaluate the clinical efficacy of LED photomodulation in reducing erythema resulting from ablative fractional CO_2 laser resurfacing.

MATERIALS AND METHODS Randomly selected facial halves of 10 Korean subjects (Fitzpatrick skin type III–IV) were treated using a 635-nm wavelength LED array immediately after full-face fractional laser skin resurfacing. Each participant was subsequently treated with LED daily for the following 7 days. Clinical photographs, subjective physician assessment, and chromometer erythema index were used to track the results, with clinical improvement assessed using a 5-point grading scale.

RESULTS The postlaser erythema resolved faster on the experimental side than the control side, with improvements noted according to physician assessment and chromometer erythema index. Statistically significant improvements between the two sides were first noted on day 4.

CONCLUSION Treatment using a 635-nm-wavelength LED array decreases the intensity and duration of post-fractional CO_2 laser treatment erythema.

The authors have indicated no significant interest with commercial supporters.

Fractional carbon dioxide (CO_2) laser resurfacing has become widely used in the treatment of photodamage and scarring because of its marked clinical efficacy and low post-treatment side-effect profile. Transient erythema, edema, and xerosis of the treated skin are the most common side effects associated with treatment, whereas severe or permanent complications are rare.[3] Nevertheless, despite the limited recovery period after fractional laser resurfacing, patients often report that the associated skin erythema and edema prevent them from continuing immediately with their regular activities of daily living.

Light-emitting diode (LED) photomodulation is a nonthermal technology used to modulate cellular activity with light,[4] whereby photomodulation refers to a photorejuvenation effect using a model of nonthermal cellular stimulation with low-energy, narrow-band light at specific pulse sequences and durations.[5] LED therapy using a variety of red, blue, and yellow wavelengths has been reported to accelerate cutaneous wound healing after various injuries, including surgical procedures and radiation.[6,7]

The purpose of this study was to evaluate the effectiveness of a 635-nm nonthermal LED array in

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reducing the intensity and duration of post-fractional laser erythema.

Materials and Methods

After the Institutional Review Board of Chung-Ang University Hospital approved this study, 10 volunteers (ages 29–38, Fitzpatrick skin type III–IV) were enrolled. Written informed consent was obtained from all participants after the risks and benefits of the procedure were explained in detail. Enrolled participants were able to freely terminate participation in the study at any time. Subjects were excluded if they reported a history of keloid scars, active cutaneous inflammation, or undergoing any ablative or nonablative laser resurfacing within the preceding 6 months.

Before laser resurfacing, all treatment areas were cleansed using a standard facial cleanser. A lidocaine-based topical anesthetic cream (EMLA, Astra Pharmaceuticals, Westborough, MA) was then applied for 30 minutes. After this anesthetic was removed, the entire face was treated using a fractional CO_2 laser with a wavelength of 10,600 nm (Qray-FRX, Diosis Inc., Seoul, Korea), a pulse duration of 25 mJ, and a spot density of 400 microscopic treatment zones/cm^2 (Figure 1A).

Immediately after the laser treatment, half of the face was treated using an LED photomodulation device (Smartlux, Medmix, Seoul, Korea) while the other side received no postlaser treatment and was covered with an opaque material. Towels or eye shields were placed over patients' eyes to protect them from the bright light source (Figure 1B). During the photomodulation treatment, the device delivers 635- $\pm$ 6-nm light at a power density of 75 mW/cm^2. In all cases, subjects were treated for 15 minutes continuously (not pulsed) every day for 7 days.

The same photographer photographed participants immediately using identical camera settings and lighting after the initial laser treatment and on post-treatment days 2, 4, 6, 8, and 14 (Canon EOS40D, 10.0 megapixels, Tokyo, Japan). At each time point, erythema and edema were scored using a 5-point grading scale (0 = none, 1 = trace, 2 = mild, 3 = moderate, and 4 = severe).

The effectiveness of the LED treatment was evaluated using a skin color measuring device (Chromameter CR-400, Minolta Co., Tokyo, Japan). For each subject, the investigator assessed the erythema index was at 10 separate regions on the right and left sides of the face. The system employed here can measure spectrometric reflectance data and quantifies colors according to three individual criteria ($L^*a^*b^*$ system): lightness (L^*), redness or greenness (a^*), yellowness or blueness (b^*).

All data were statistically analyzed using the paired *t*-test with SPSS version 13.0 (SPSS, Inc., Chicago, IL). In all cases, differences were considered statistically significant when $p < .05$.

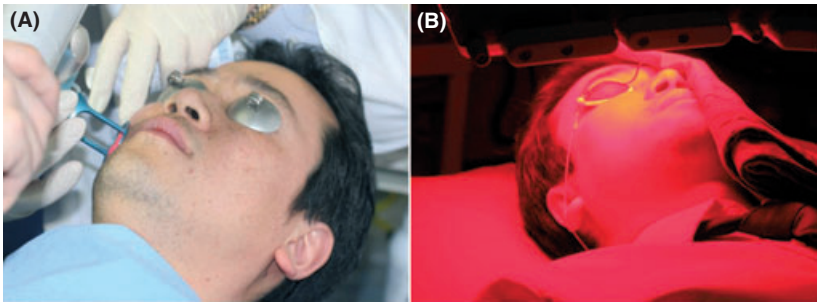

Figure 1. (A) The full face was treated using a fractional carbon dioxide laser. (B) The untreated side was covered with an opaque material. The other side of the face was treated using the light-emitting diode device for 15 minutes.

Results

All 10 patients completed the study. In all participants, marked rapid improvements in the LED-irradiated side were evident in photographic assessment (Figures 2, 3), with the post-treatment erythema resolving more rapidly on the treatment side than the control side. These differences in erythema improvement were verified using the skin color measuring device, with statistical significance first reached on day 4 ($p < .05$) (Figure 4).

Changes in the physician-assessed mean degree of erythema are presented in Figure 5. Specifically, the post-treatment erythema resolved more quickly on the experimental side than the control side, with a mean duration of erythema of 8.7 ± 0.9 days for the control side and 7.1 ± 1.2 days for the experimental side. Differences in improvement of post-treatment erythema between the two sides first reached statistical significance on day 4 ($p < .05$). Furthermore, the physician-assessed degree of edema occurring after the laser treatment resolved more rapidly on the experimental side (Figure 6), with the edema lasting for an average of 6.2 ± 0.6 days on the control side and 5.3 ± 0.8 days on the experimental side, although these differences did not reach statistical significance.

None of the patients had any permanent hypo- or hyperpigmentation or long-term side effects.

Discussion

Fractional CO_2 laser resurfacing is one of the better choices for the treatment of photoaging, acne scarring, and other signs of severe photodamage.[8,9] This technology unites the concept of fractional photothermolysis with an ablative 10,600-nm wavelength laser to the theory of fractional photothermolysis. It thermally ablates a fraction of the skin, allowing the intervening regions of normal skin to rapidly repopulate the ablated columns of tissue. Histologic and ultrastructural evidence indicate that fractional laser resurfacing enhances wound repair and promotes subsequent new collagen formation and deposition.[10–12]

Nonetheless, even under ideal conditions, full-face laser resurfacing may cause erythema that can last 6 weeks or longer. Laser resurfacing also carries the

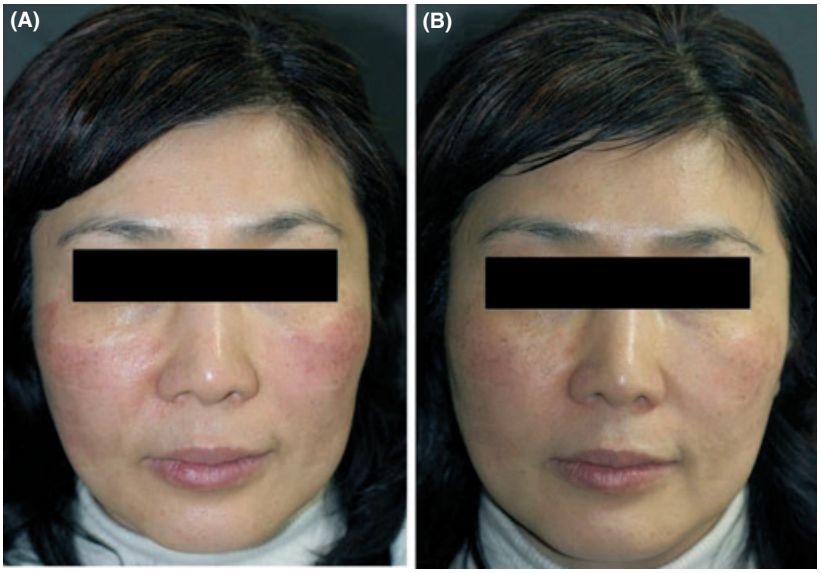

Figure 2. A 38-year-old woman (A) immediately and (B) 4 days after full-face fractional carbon dioxide laser treatment. Efficacy in decreasing of erythema was better on the light-emitting diode–treated facial half (left cheek) than the untreated half.

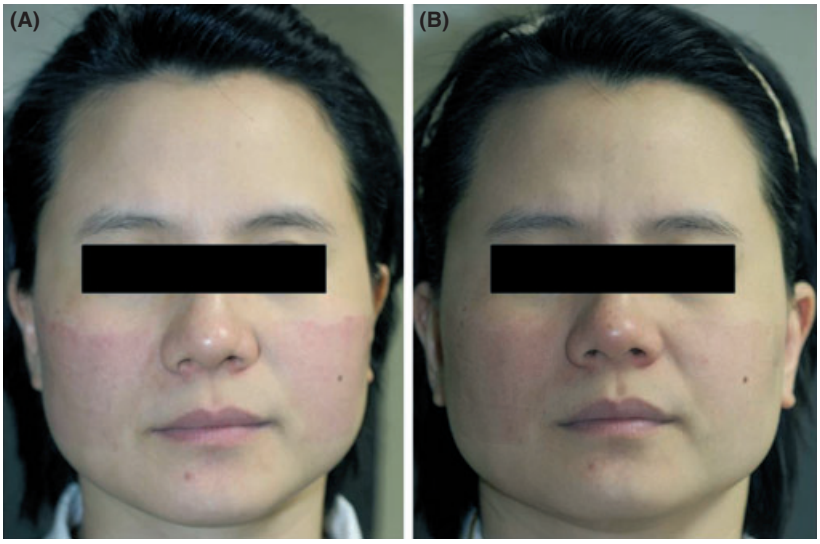

Figure 3. A 32-year-old woman (A) immediately and (B) 6 days after full-face fractional carbon dioxide laser treatment. Efficacy in lessening erythema was better on the light-emitting diode–treated facial half (left cheek) than untreated half.

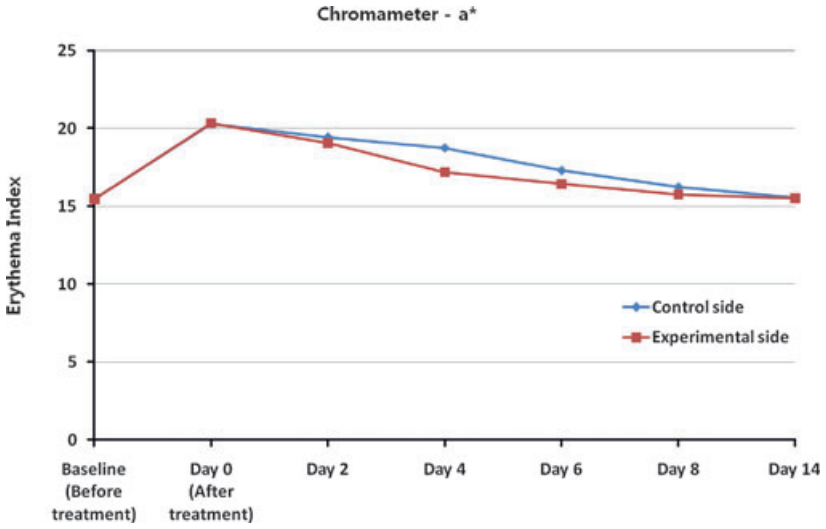

Figure 4. Erythema index using skin color measuring device. Differences in erythema improvement were statistically significant on day 4 ($p < .05$)

risks of permanent hypo- or hyperpigmentation and scarring, although the most common side effects associated with fractional CO_2 laser resurfacing are erythema and edema.[13] Because even these minor complications can affect patient adherence, reducing post-treatment erythema and edema could serve to benefit patient and provider alike.

Skin hydration through emollient use has been used after fractional laser resurfacing. In the present study, physician assessment and skin color measuring device–validated erythema index were used to evaluate whether LED photomodulation decreased the duration of post-treatment erythema and edema after full-face fractional CO_2 laser skin resurfacing. The results presented here demonstrate that this modality successfully decreased the intensity and duration of postfractional CO_2 laser erythema and edema. This study is also the first to document LED photomodulation as an effective treatment for

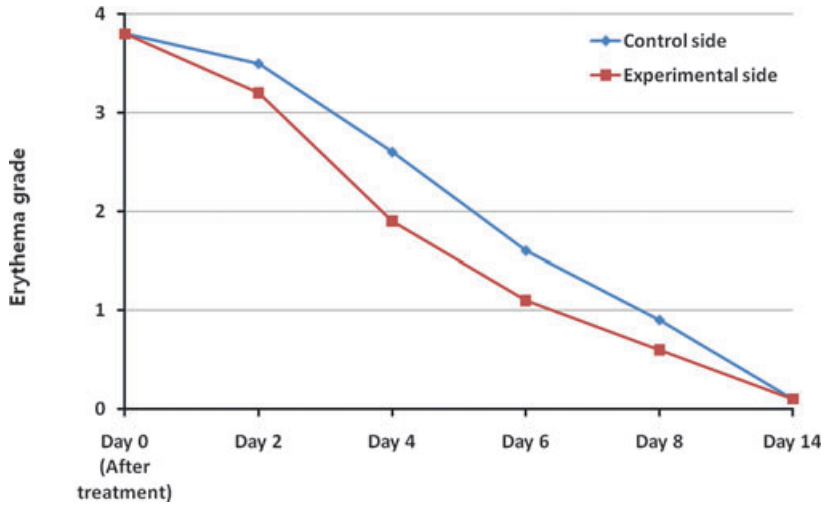

Figure 5. Physician-assessed degree of erythema. Erythema on the experimental side improved faster than on the control side. Differences in improvement between the sides were statistically significant at day 4 ($p < .05$)

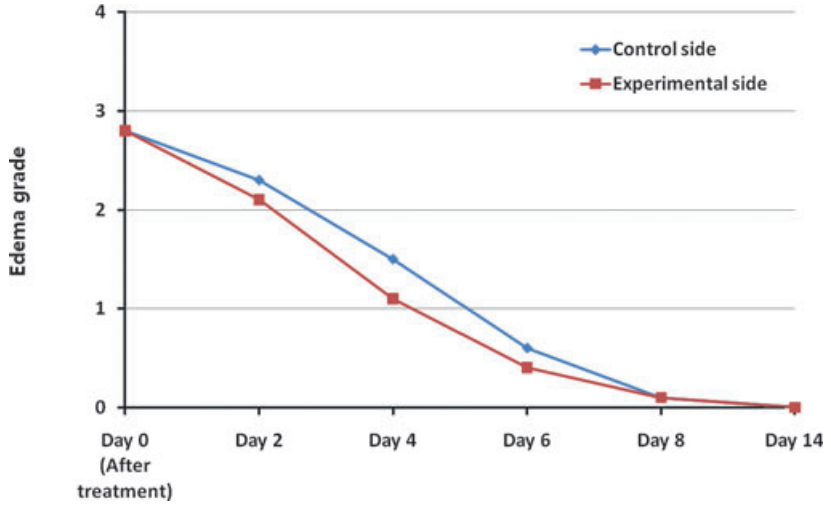

Figure 6. Physician-assessed degree of edema. Erythema on the experimental side improved faster than on the control side, although the differences were not statistically significant.

reducing erythema and edema after fractional CO_2 laser therapy.

Early studies in animals and humans demonstrated that LED photomodulation diminished wound size and decreased skin inflammation and ulceration,[14,15] with subsequent data suggesting that this may occur through the stimulation of fibroblast activity through mitochondrial functional enhancement.[16] Varying LED fluences and pulse duration also result in upregulation of procollagen synthesis and downregulation of matrix metalloproteinase activity in human fibroblast cultures.[17,18] This resulting fibroblast stimulation is probably responsible for enhancing wound healing and decreasing inflammation. The data from these prior studies thus probably explain why there was less erythema and edema observed with LED treatment in the setting of postfractional treated skin.

In conclusion, LED photomodulation not only represents an effective treatment for reducing

erythema and edema after fractional CO_2 laser therapy, but also has several significant advantages, including ease of application, predictable outcomes, no known side effects, and limited patient discomfort. Accordingly, we recommend the use of LED photomodulation after fractional and ablative laser treatment in our clinics. In our experience, patients are satisfied with the noticeable associated improvements in skin healing and postlaser comfort, as well as their ability to return to their regular activities more quickly.

Because this was a small pilot study, additional controlled trials are necessary, including studies with larger cohorts of patients, patients with a wider variety of skin types, and multiple treatment sessions. It is impossible to compare the efficacy of LED photomodulation with that of other treatment modalities. A second limitation of this study is that all patients were treated using the same LED and laser parameters; better clinical results may be achieved by modulating the LED wavelength, power density, and time. Additional studies are needed to determine the optimal settings for LED photomodulation when treating postfractional laser resurfacing erythema and edema.

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