Journal of Cosmetic and Laser Therapy. 2005; 7: 196–200

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ORIGINAL ARTICLE

A study to determine the efficacy of combination LED light therapy (633 nm and 830 nm) in facial skin rejuvenation

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Abstract

Background. The use of visible or near infrared spectral light alone for the purpose of skin rejuvenation has been previously reported. A method of light emitting diode (LED) photo rejuvenation incorporating a combination of these wavelengths and thus compounding their distinct stimulation of cellular components is proposed.

Objective. To assess the efficacy and local tolerability of combination light therapy in photo rejuvenation of facial skin.

Methods. Thirty-one subjects with facial rhytids received nine light therapy treatments using the Omnilux™ LED system. The treatments combined wavelengths of 633 nm and 830 nm with fluences of 126 J/cm^2 and 66 J/cm^2 respectively. Improvements to the skin surface were evaluated at weeks 9 and 12 by profilometry performed on periorbital casts. Additional outcome measures included assessments of clinical photography and patient satisfaction scores.

Results. Key profilometry results Sq, Sa, Sp and St showed significant differences at week 12 follow-up; 52% of subjects showed a 25%–50% improvement in photoaging scores by week 12; 81% of subjects reported a significant improvement in periorbital wrinkles on completion of follow-up.

Conclusion. Omnilux™ combination red and near infrared LED therapy represents an effective and acceptable method of photo rejuvenation. Further study to optimize the parameters of treatment is required.

Key words: *LED (light emitting diode), photo aging, photo rejuvenation*

Introduction

Morphologic changes commonly associated with aging skin include development of rhytids, furrows and telangiectases. These features result from the composite effect of intrinsic or chronological and extrinsic, largely photodamage related influences (1).

The clinically prominent features of aged skin are mostly attributable to photoaging rather than chronology (2) and are especially prominent in facial skin (3).

Photoaged skin displays distinctive histological hallmarks. These include an overall reduction in quantity of collagen (4) coupled with a thickening and degradation of the dermal collagen and elastic fibres (5). The fibres of collagen become brittle and are easily fragmented (6). Dermal elastic fibres grow abundant and tortuous (7).

It is postulated that these effects result from a combination of factors at the cellular level. These include a reduction in both the amount and biosynthetic capacity of fibroblasts, decreased proliferative capacity of skin derived cells and increased expression of collagen degrading enzymes (8).

The drawbacks of using ablative methodologies such as some chemical peels and laser resurfacing for the purpose of skin rejuvenation are widely documented. The epidermal disruption associated with these treatments increases patient susceptibility to infection, and abnormal or delayed wound healing may result in scarring or altered pigmentation (7). Patients may find the considerable downtime and persistent erythema associated with these modalities unacceptable (9). Non-invasive approaches to rejuvenation are therefore quickly becoming the preference in treatment of mild rhytids and overall skin toning (10). Light emitting diode (LED) based light therapy is one such treatment.

The mechanism of light therapy necessitates absorption of a specific wavelength of light by a photoacceptor molecule, which may be endogenously produced or synthesized and applied exogenously to the host. Irradiation of the photoacceptor generates production of cytotoxic singlet oxygen. A cascade of cellular responses is thus initiated—resulting in modulation of cell function, cell

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(Received 1 July 2005; accepted 22 September 2005)

ISSN 1476-4172 print/ISSN 1476-4180 online © 2005 Taylor & Francis
DOI: 10.1080/14764170500370059

proliferation and repair of compromised cells. The term describing this process of ''cell function enhancement'' is photobiomodulation (11,12).

The selection of the appropriate wavelength is fundamental to light therapy as light reactions display specificity to irradiation wavelengths (13). Lam et al. (14) demonstrated that *in vitro* irradiation of fibroblasts with 633 nm wavelength light increased procollagen synthesis four-fold from baseline, while exhibiting no effect on the activity of the collagen-regulating proteolytic enzymes collagenase and gelatinase. Irradiation with this red light increased fibroblastic growth factor synthesis from photoactivated macrophages and accelerated mast cell degeneration (15).

Light at 830 nm (near infrared) wavelength is absorbed in the cellular membrane rather than in cellular organelles which remain the target when using light in the visible spectrum. Irradiation at 830 nm has accelerated fibroblast-myofibroblast transformation and mast cell degranulation. In addition, chemotaxis and phagocytic activity of leucocytes and macrophages is enhanced on cellular stimulation by this wavelength (16,17).

It is hypothesized that the synergy of 633 nm and 830 nm wavelength light will combine these effects to enhance fibroblast proliferation and thus increase collagen synthesis, as well as stimulating inflammatory cell lines such as mast cells and macrophages. This may result in positive skin rejuvenation results. The aim of this study was therefore to assess the skin rejuvenation effects, over a 12-week period, of a combination of 633 nm and 830 nm light therapy in subjects presenting classic features of skin aging.

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Materials and methods

Subjects

Fifty subjects recruited from the Inveresk Consumer Unit subject panel in June 2004 were screened for study inclusion: 38 subjects from this group (age range 35–57 years, mean age 46.2 years) were selected for study participation.

Inclusion criteria were presentation of wrinkles or crow's feet in the periorbital region. Subjects displaying photodamage grade I–III in conformity with the Glogau (18) scale were also included.

Subjects who had undergone laser treatment or any other ablative/nonablative cosmetic intervention within the last six months, including injectables or fillers, were excluded. Subjects with any history of laser treatment or trauma to the test site were also excluded, as were those with Fitzpatrick (19) scale skin type VI.

The study was granted local research ethics committee approval and all subjects gave written consent to the treatment.

Light source

Two separate hinged planar arrays of light emitting diodes were used: 1) Omnilux Revive™ delivering non-coherent red light at a wavelength of 633 ± 3 nm and an intensity of 105 mW/cm^2 (a total dose of 126 J/cm^2 after 20 minutes exposure), and 2) Omnilux Plus™delivering non-coherent light at a wavelength of 830 ± 5 nm, 55 mW/cm^2 intensity and a total dose of 66 J/cm^2 on 20 min exposure. (Omnilux Revive™ and Omnilux Plus™, Phototherapeutics Ltd, Altringham, Manchester, UK.)

Treatment

All subjects were treated at Inveresk CRU, Edinburgh, Scotland, UK. Each subject received a total of nine light therapy treatments over a five-week period.

Subjects were irradiated with 830 nm light source for 20 minutes (55 mW/cm^2, 66 J/cm^2) on days 1, 3, 5, 15, 22 and 29. The 633 nm irradiations (105 mW/cm^2, 126 J/cm^2), also of 20 minutes' duration, were performed on days 8, 10 and 12.

The light source was positioned approximately 1 cm from the subject's face (nose tip) for the duration of all treatments.

Before each treatment the subject's skin was cleansed using a Lite-Red™ cleanser followed by a five-minute exfoliation using a polyethylene based exfoliant. Protective eyewear was positioned for all treatments.

Assessment

Clinical grading of wrinkles and photodamage according to the Glogau photodamage classification scale was conducted at baseline. Clinical assessments of skin smoothness using the tactile roughness grading scale (20) and Fitzpatrick scale skin type of all subjects were also recorded.

Baseline digital photography (Canon® 300D digicam) was performed on all subjects: two exposures to the bilateral periorbital regions (eyes open and closed) and two full-face exposures (eyes open and closed). This was repeated at weeks 6, 9 and 12. Lighting and ambient conditions for photography were standardized throughout the trial. Image analysis and photoaging assessment were conducted by the principal investigator.

Bilateral cast impressions of the periorbital and temporal regions were conducted at baseline and weeks 6, 9 and 12 using Provil Novo™ dental impression material. Cast position was standardized at all follow-up points. Cast analysis was conducted by profilometry at Taylor Hobson, Leicestershire, UK, using a TALYSURF® CLI 2000 instrument with non-coherent 10 mm laser triangulation gauge.

Cast analysis was performed at baseline and weeks 9 and 12.

Statistical methods

Parametric analysis of covariance (ANCOVA) was used to assess changes from baseline for each profilometry parameter, maximum depth of furrows, mean density of furrows and developed area. The model included terms for subject, time point, side (left or right periorbital region) and baseline value.

The normality assumptions underlying the statistical analysis were examined using probability plots.

Results

Fifty subjects were screened and 38 were selected for inclusion into the trial; 31 subjects completed the trial, 6 subjects voluntarily withdrew from the study: 4 failed to return for follow-up and 2 withdrew due to personal circumstances. One subject withdrew as result of a mild facial herpes simplex adverse reaction. These subjects' data were excluded from analysis.

Definitions of profilomety parameters studied are shown beneath Table I.

Sq measurement represents the root mean square roughness of a surface and displayed a statistically significant decrease from baseline at both 9 and 12 weeks ($p<0.001$) (Table I).

Sa measurement showed a statistically significant decrease from baseline at week 12 only ($p<0.001$). Parameters Sp ($p=0.008$) and St ($p=0.007$) also displayed a statistically significant decrease in post-baseline values at week 12. Measurements Sz and Sv displayed no significant changes from baseline at either time point.

In the evaluation of skin furrows, the maximum furrow depth did not alter significantly from baseline at either time point. However, the mean density of furrows was significantly reduced at 9-week follow-up ($p=0.008$) (Table II).

Photoaging assessment scores showed significant improvement at all follow-up points (Table III): 51.6% of the study population displayed a 25%–50% improvement in photoaging scores at 12-week follow-up and 12.9% displayed improvement in the 50%–75% bracket.

Softening of periorbital wrinkles was reported by 83.9% of subjects at 9 weeks and 80.6% at 12 weeks (Table IV). At 9 weeks, 66.8% of subjects personally reported the effect of treatment to be ''excellent'' or ''good'' in terms of periorbital wrinkle softening; 58% reported this effect at 12-week follow up.

In assessment of overall tone, softness, smoothness, clarity, elasticity and firmness of skin in the treatment area (Table V), the majority of patients reported improvements in softness, smoothness and firmness at all time-points. However, other assessment measures varied over time.

During the course of follow-up, no adverse reaction scores were reported for pain, blistering, ulceration or scarring. Mild erythema was recorded in one subject (3.2%) at day 8 and by seven subjects (23%) at day 15 follow-up.

Discussion

The profilometry measure Sq (root mean square roughness of the analysis surface) showed significant improvement of over 13% at week 9 and 27% at week 12. The measure Sa (roughness average) displayed a significant decrease from baseline of 14% at week 12. Both Sp (maximum profile peak height) and St (maximum height of the profile) measurements displayed statistically significant decreases at week 12 of 3% and 1.2% respectively.

Table I. Mean profilometry readings for measurements Sq, Sa, Sp, St, Sv and Sz, at 9- and 12-week follow-up.

	Surface profile measurement					
	Sq	Sa	Sp	St	Sv	Sz
Baseline measurement	0.0655	0.0428	0.2693	0.60607	0.34180	0.38274
Week 9	0.0565	0.0428	0.2563	0.59007	0.3388	0.40074
Post treatment change from baseline (95% CI)	−0.009	0	−0.013	−0.016	−0.003	0.018
p-value	<0.001	0.83	0.23	0.4	0.85	0.1
Week 12	0.0475	0.037	0.2383	0.5531	0.3258	0.36674
Post treatment change from baseline (95% CI)	−0.018	−0.006	−0.031	−0.053	−0.016	−0.016
p-value	<0.001	<0.001	0.008	0.007	0.3	0.14

Sq=Root mean square roughness of the analysis surface. Sa=Roughness average—area between the roughness profile and its mean line or the integral of the absolute value of the roughness profile height over the evaluation length. Sp=Maximum profile peak height. St=Maximum height of the profile—the vertical distance from the deepest valley to the highest peak. Sv=Deepest valley of the surface. Sz=Average maximum height of the profile.

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Table II. Statistical analysis of furrow measurements—reduction from baseline at weeks 9 and 12.

	Surface profile measure	Post-treatment reduction from baseline (95% CI)	*p*-value
Week 9:	Max depth (mm)	0.003	0.76
	Mean density (cm/cm^2)	−0.70	0.008
Week 12:	Max depth (mm)	−0.012	0.22
	Mean density (cm/cm^2)	−0.06	0.83

Table III. Mean photoaging assessment scores at all follow-up points.

Follow-up point	0%–25% improvement (%)	25%–50% improvement (%)	50%–75% improvement (%)	75%+ improvement (%)
Week 6	64.5	25.8	9.7	0
Week 9	22.6	58.1	16.1	3.2
Week 12	35.5	51.6	12.9	0

Table IV. Subject responses in wrinkle softening and overall effect of treatment.

		Softening of wrinkles (%)		Effect of treatment (%)				
Area	Time point	Yes	No	Excellent	Good	Moderate	No effect	Poor
Peri-orbital region:	Week 6	61.3	38.7	9.7	32.3	29	29	0
	Week 9	83.9	16.1	12.9	54.8	16.1	16.1	0
	Week 12	80.6	19.4	16.1	41.9	22.6	19.4	0

Table V. Subjective reports of improvements in skin measurements at all follow-up points (%).

Follow-up assessment	Tone (%)	Softness (%)	Smoothness (%)	Clarity (%)	Elasticity (%)	Firmness (%)
Week 6	48	65	68	48	35	52
Week 9	68	84	81	65	48	52
Week 12	42	65	74	45	42	48

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The cast analysis measurements generally exhibited improvements at both weeks 9 and 12, although the associated *p*-values were not statistically significant.

Photoaging scores displayed an overall improvement in visible features of skin aging at all follow-up points: 58.1% and 51.6% of subjects presented 25%–50% improvement at 9 and 12 weeks follow-up respectively. Improvements perceived at 50%–75% were seen in 16.1% and 12.9% of subjects at 9 and 12 weeks respectively.

The subjective experience of the majority of subjects treated was an overall improvement in skin softness, smoothness and firmness in the treatment area.

Subjective softening of wrinkles was consistently reported in the periorbital region (80.6% at 12 weeks). Local tolerance of the treatment was good throughout the group, with the majority of the trial subjects rating the treatment as ''good to excellent''.

In conclusion, the treatment was well received by the subjects and improvement in the appearance of fine lines and wrinkles was reported. The profilometry measures Sq, Sa, Sp and St displayed significant improvements after treatment.

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