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Instrumental Evaluation of Skin Structural Parameters After 56 Days of Use of a Home-Use LED Photobiomodulation Device

Mar Miñano Núñez [1,2]

[1] Escuela Superior de Ingeniería y Tecnología, Universidad Internacional de La Rioja (UNIR), Avenida de la Paz 137, 26006 Logroño, La Rioja, Spain; mar.minano@unir.net
[2] Femtechnology S.L., Vía de las Dos Castillas 9 C, 28224 Pozuelo de Alarcón, Madrid, Spain

Abstract

Light-emitting diode (LED) photobiomodulation has emerged as a non-invasive approach for skin quality improvement and reduction in visible aging signs. This study evaluated the efficacy and tolerability of a combined skincare regimen consisting of a home-use silicone LED facial mask emitting red light used together with a cosmetic serum for skin rejuvenation. An open, single-centre clinical study without a control group was conducted in 20 healthy female volunteers aged 40–55 years presenting visible facial wrinkles and skin imperfections. Participants used the LED mask twice daily for 10 min over 56 days, each session being followed by application of a standardized cosmetic serum, so that the LED device and the serum were evaluated as a single combined regimen. Skin evaluations were performed at baseline (D0), after 28 days (D28), and after 56 days (D56) using three-dimensional skin topography (AEVA-HE), high-frequency ultrasound imaging (Ultrascan® UC22), biomechanical measurements (Cutometer® dual MPA 580), and pigmentation analysis (Mexameter® MX18). In the exploratory analysis, a statistically significant improvement in the Cutometer firmness parameter (F4) was observed at D56 compared with baseline ($p = 0.03$). Changes in elasticity, pigmentation, wrinkle-related topographic measurements and dermal thickness did not reach statistical significance and are reported only as non-significant numerical trends. The treatment was well tolerated, with no significant skin reactions observed. These preliminary findings suggest that a combined regimen incorporating home-use LED photobiomodulation and a cosmetic serum may be associated with an improvement in skin firmness. Because the study was uncontrolled and the LED device was used together with a serum, the observed changes cannot be attributed to photobiomodulation alone and should be interpreted as preliminary.

Keywords: photobiomodulation; LED therapy; skin aging; skin firmness; skin topography; home-use device; non-invasive skincare; Cutometer; dermal thickness; facial rejuvenation

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1. Introduction

Non-invasive procedures aimed at improving skin appearance and reducing visible signs of aging have experienced substantial growth in recent decades. The demand for aesthetic treatments capable of delivering visible improvements while minimizing discomfort, recovery time, and procedural risks has driven the rapid development of non-surgical dermatological technologies [1–3]. Reports from aesthetic medicine societies indicate that non-invasive treatments continue to increase at a faster rate than surgical procedures, reflecting a global shift toward minimally invasive approaches for skin rejuvenation and dermatological care [1–3].

Among the technological approaches currently used in aesthetic dermatology, energy-based devices have gained considerable attention. These include lasers, intense pulsed light systems, radiofrequency devices, and light-based technologies designed to stimulate biological responses in skin tissues without inducing ablative damage [4–6]. Unlike ablative treatments, these approaches aim to induce controlled biological stimulation while preserving the structural integrity of the epidermis and dermis, making them suitable for repeated applications and long-term skin maintenance [5].

Photobiomodulation (PBM) refers to the application of low-intensity light at specific wavelengths capable of inducing beneficial biological responses in cells and tissues [6–8]. PBM typically involves visible or near-infrared light delivered at relatively low energy densities in order to modulate cellular activity rather than induce thermal effects. The interaction between photons and intracellular chromophores—particularly those located in the mitochondrial respiratory chain—can initiate a cascade of biochemical processes including increased adenosine triphosphate (ATP) production, modulation of reactive oxygen species, and activation of transcription factors involved in tissue repair and cellular proliferation [7–9]. These mechanisms are considered central to the regenerative effects associated with photobiomodulation therapies.

Light-emitting diode (LED) systems represent one of the most widely used technologies for delivering photobiomodulation in dermatological applications. LED-based phototherapy has been investigated for medical applications for several decades, particularly following the development of low-level light therapy technologies [8–11]. LED phototherapy offers several advantages compared with other energy-based modalities, including the ability to deliver non-coherent light at controlled wavelengths with minimal thermal effects and a favorable safety profile [9,11]. For these reasons, LED-based treatments are generally considered non-ablative, atraumatic, and suitable for repeated use in cosmetic dermatology [10].

Different wavelengths of LED light have been associated with distinct biological and dermatological effects. Blue light wavelengths have been widely used in the treatment of acne due to their antimicrobial activity against Cutibacterium acnes, while green and yellow wavelengths have been investigated for their effects on pigmentation disorders and vascular conditions [12–14]. In contrast, red and near-infrared wavelengths have attracted particular interest in skin rejuvenation research due to their deeper penetration into the dermis and their potential influence on fibroblast activity and collagen synthesis [15–17]. Several experimental and clinical studies have reported that red LED irradiation may stimulate dermal fibroblasts, increase collagen production, improve microcirculation, and modulate inflammatory pathways involved in skin aging processes [15–20]. Clinical investigations using LED phototherapy have also suggested improvements in skin texture, elasticity, and wrinkle appearance following repeated treatments [16–18,21].

In aesthetic dermatology, these biological effects are particularly relevant because structural changes within the dermis play a central role in the development of visible signs of aging. Age-related degradation of collagen fibers, alterations in extracellular matrix organization, and reduced fibroblast activity contribute to decreased skin elasticity and the progressive formation of wrinkles over time [18,22–24]. Photobiomodulation therapies targeting these cellular processes therefore represent a promising non-invasive strategy for improving dermal structure and overall skin quality [25–27].

Recent technological advances have enabled the development of compact LED devices designed for home use [28–30]. These systems aim to extend the benefits of photobiomodulation beyond clinical environments, allowing individuals to incorporate light-based treatments into daily skincare routines. Among home-use photobiomodulation technologies, LED facial masks have become increasingly popular due to their ability to deliver

relatively uniform light exposure across large facial areas while remaining easy to integrate into personal skincare regimens [28–30].

However, despite the increasing availability of such technologies, objective clinical evidence evaluating their effects on skin structural parameters using instrumental measurements remains relatively limited [28,31]. In addition, the biological response induced by photobiomodulation can depend on several technical characteristics of the device, including wavelength, irradiance, treatment duration, and emission geometry. Because these parameters may influence the magnitude of the photobiological response, individual evaluation of specific devices remains necessary in order to better characterize their clinical effects.

Non-invasive imaging techniques and biomechanical skin measurements provide quantitative, objective information about skin structure and function that is increasingly valued in cosmetic research, allowing a more rigorous evaluation of treatment responses compared with purely subjective assessments [31,32].

However, objective instrumental evidence evaluating the effects of home-use photobiomodulation devices on structural skin parameters such as firmness, dermal thickness, and three-dimensional surface topography remains limited. Despite growing evidence supporting photobiomodulation, substantial heterogeneity exists among studies due to differences in wavelength, irradiance, treatment protocols, and device design, making direct comparison of outcomes challenging and highlighting the need for device-specific clinical evaluations. Therefore, the objective of the present study was to evaluate, using non-invasive instrumental techniques, the effects of repeated use of a home-use LED photobiomodulation facial mask on dermal structural parameters, biomechanical skin properties, and visible signs of facial skin aging. Recent reviews have further documented the rapid expansion of LED photobiomodulation in cosmetic dermatology and its transition from professional systems to home-use consumer devices, while noting that the strength and consistency of the available evidence still vary across indications [33–35].

2. Materials and Methods

2.1. LED Photobiomodulation Device

The photobiomodulation system evaluated in this study consisted of a home-use silicone LED facial mask (Skinvity® Silicone LED Mask; Femtechnology S.L., Pozuelo de Alarcón, Spain) designed to deliver non-thermal light stimulation to facial skin (Figure 1). The device is a flexible silicone mask incorporating an array of light-emitting diodes distributed across the facial surface to ensure homogeneous illumination of the treatment area. The mask is connected to an external control unit allowing adjustment of treatment parameters. During the study protocol, the mask was operated in red-light mode at the maximum intensity level (level 5) according to the manufacturer's instructions. The same treatment parameters were used for all volunteers, with no individualisation: red-light mode at the maximum level (level 5), 10 min per session, applied twice daily. The device has five levels, and the selected level determines the treatment time, with the maximum level (level 5) corresponding to a 10-min session. According to the manufacturer, the device operates at an irradiance of approximately 25–30 mW/cm^2. The mask is secured to the face with adjustable straps to ensure stable positioning during treatment and automatically switches off at the end of each treatment cycle. Following each treatment session, participants applied a facial cosmetic serum (Skinvity®, Femtechnology S.L., Pozuelo de Alarcon, Spain) provided as part of the study protocol. The serum was an oily solution with the following declared composition (INCI): Snail Secretion Filtrate, Propylene Glycol, Propanediol, Pentylene Glycol, Glycerin, Camellia Japonica Seed Oil, Aqua (Water), Sodium Hyaluronate, Ascorbyl Stearate, Isostearic Acid, Ascorbic Acid, Sodium Acrylates Copolymer, Lecithin, Parfum (Fragrance), and Tetrasodium EDTA. Several of these

ingredients—notably sodium hyaluronate, ascorbic acid and its derivative ascorbyl stearate, and snail secretion filtrate—are cosmetically active and may contribute independently to skin-surface, hydration and radiance-related effects, which is relevant to the interpretation of the intervention as a combined regimen. All treatments were performed according to the manufacturer's instructions. According to manufacturer specifications, the red-light mode used in this study emits light at four wavelengths: 630–635 nm, 830–835 nm, 930–935 nm, and 1072 nm. The device operates at an irradiance of approximately 30 mW/cm^2 at maximum intensity, resulting in an estimated fluence of approximately 18 J/cm^2 per session (30 mW/cm^2 × 600 s). The value of approximately 30 mW/cm^2 corresponds to the total irradiance specified by the manufacturer. To characterise the spectral output of the device more directly, the red-light mode of the facial mask was additionally measured by spectroradiometry (EVERFINE HAAS-1200). The measured spectrum confirmed a dominant red band peaking at 631 nm (FWHM 16.2 nm) together with two near-infrared bands centred at approximately 835 and 935 nm; the nominal 1072 nm band lies above the 380–1000 nm range of the instrument and was therefore not captured. Expressed as a fraction of the total measured radiant flux (380–1000 nm), the red region (400–700 nm) accounted for approximately 49% of the output and the near-infrared region (above 700 nm) for approximately 51%, the 835 nm band being the more intense of the two near-infrared components. These proportions reflect radiant flux (relative optical power) rather than per-wavelength irradiance, and separating the individual near-infrared bands would require integration of the raw spectral data; they nonetheless provide a measured estimate of the relative optical contribution of the red and near-infrared components of the device (Section 4). The maximum intensity setting (level 5), which on this device corresponds to a 10-min session, was selected so that the delivered dose would fall within the range reported to be effective for skin photobiomodulation. Reviews of photobiomodulation dosimetry recommend power densities below 100 mW/cm^2 together with energy densities on the order of a few to several tens of J/cm^2 for low-mitochondrial-density tissues such as skin [36], and controlled trials of red and near-infrared light for facial rejuvenation have reported increased intradermal collagen density using red-band treatment doses of approximately 8.5–9.6 J/cm^2 [14]. The irradiance (approximately 30 mW/cm^2) and per-session fluence (approximately 18 J/cm^2) used here therefore lie within this effective range, and the fixed 10-min, twice-daily protocol reflects typical home-use photobiomodulation conditions [13,37] rather than titration to an individual clinical endpoint. In particular, a home-use device emitting at comparable red and near-infrared wavelengths (637 and 854 nm) has been reported to significantly improve skin elasticity and texture in a controlled split-face trial [29], supporting the relevance of this red and near-infrared wavelength combination for home-use facial photobiomodulation.

2.2. Study Design

This study was conducted as a single-centre open-label clinical study to evaluate the anti-wrinkle and firming efficacy of a cosmetic treatment consisting of a Silicone LED Mask and Facial Serum (Skinvity®, Femtechnology). The study was performed by Dr. Goya Análisis S.L. (Alcalá de Henares, Spain), a contract research organization (CRO) specialized in dermatological and cosmetic clinical testing. The experimental phase was conducted between September and November 2023 (internal study code: 2317080). The study was conducted following general good-practice principles for the conduct and reporting of cosmetic efficacy and tolerability testing in human volunteers.

Repeated within-participant measurements were performed at three time points: baseline (D0), after 28 days of treatment (D28), and after 56 days of treatment (D56).

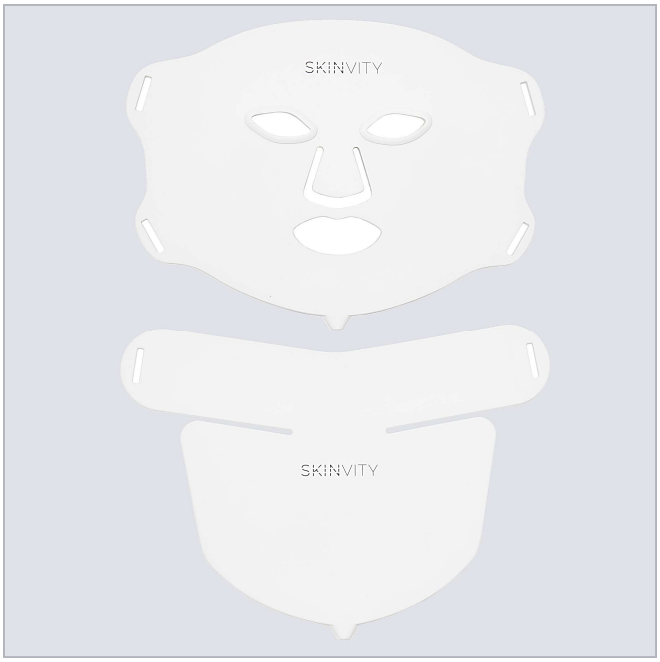


Figure 1. Home-use silicone LED facial mask evaluated in the study (Skinvity®, Femtechnology S.L., Pozuelo de Alarcón, Spain), comprising a flexible facial mask (**top**) and a complementary neck/décolletage piece (**bottom**). The device was used in red-light mode at its maximum level (level 5), corresponding to a 10-min session, applied twice daily.

2.3. Participants

A total of 20 female volunteers aged between 40 and 55 years presenting visible facial wrinkles and skin imperfections were enrolled in the study. Participants were recruited following verification of inclusion and exclusion criteria through a screening questionnaire and dermatological evaluation. Each volunteer provided written informed consent prior to participation.

Inclusion criteria. Participants were eligible if they: were female; were between 40 and 55 years of age; presented visible facial wrinkles or skin imperfections; were in good general health; agreed to participate voluntarily and signed written informed consent; and had discontinued the use of anti-aging cosmetic products 7 days before the start of the study.

Exclusion criteria. Participants were excluded if they presented: dermatological diseases affecting the face (eczema, psoriasis, dermatitis); hypersensitivity to cosmetic products; active skin lesions in the treatment area; recent aesthetic procedures (laser treatments, fillers, or botulinum toxin within the previous 6 months); treatment with medications known to affect skin physiology (retinoids, corticosteroids, antibiotics, antihistamines); pregnancy or breastfeeding; or participation in another clinical study during the study period.

2.4. Treatment Protocol

Participants were instructed to perform the treatment twice daily for 56 consecutive days following a standardized protocol. The protocol used a fixed-duration regimen defined by the manufacturer's instructions and was not titrated to a clinical endpoint (for example, erythema or a predefined skin response); all participants followed the same fixed schedule and settings for the full 56 days, with no individualisation. Each treatment session consisted of cleansing the facial skin; positioning the Skinvity silicone LED mask on the face using the adjustable strap; activating the device in red-light mode at maximum intensity (level 5); wearing the device for 10 min; and allowing the device to automatically switch off

at the end of the treatment cycle. Participants performed one session in the morning and one in the evening. Immediately after each LED session, participants applied the Skinvity facial serum provided as part of the study protocol. During the study period, volunteers were instructed not to use additional anti-aging or depigmenting cosmetic products on the face.

2.5. Experimental Procedure

Prior to the beginning of the study, participants completed a washout period of 7 days, during which the use of cosmetic products on the face was discontinued. At baseline (D0), participants underwent dermatological examination, instrumental skin measurements, and photographic documentation of facial skin and received instructions on device use and treatment procedures. Follow-up instrumental measurements were performed at D28 and D56. At the end of the study, participants completed a subjective evaluation questionnaire assessing treatment perception, tolerability, and perceived efficacy.

2.6. Instrumental Assessment of Skin Parameters

All measurements were conducted in a controlled environment with standardized conditions: temperature 20 ± 2 °C and relative humidity 40–60%. Participants remained in the test room for 10 min of acclimatization before measurements were taken. The facial skin was free of makeup and cosmetic products during evaluation.

2.6.1. Wrinkle Analysis

Wrinkle morphology and skin surface topography were assessed using the AEVA-HE 3D skin analysis system (Eotech, Marcoussis, France). This device uses fringe projection combined with stereometry to generate high-resolution three-dimensional images of the skin surface. Measurements were performed on the full facial surface. The following parameters were analyzed: wrinkle density (%) and wrinkle object number. Lower values correspond to a reduction in wrinkle presence.

2.6.2. Dermal Thickness and Density

Dermal structure was evaluated using high-frequency ultrasound imaging (Ultrascan® UC22, Courage + Khazaka Electronic GmbH, Cologne, Germany). Ultrasound waves penetrate the skin and are reflected by tissue structures with different acoustic properties. The reflected signals are converted into electrical impulses that generate B-scan images of skin layers. Measurements were performed on the cheek area. The following parameters were analyzed: dermal thickness and dermal density. Higher values correspond to improved dermal structural integrity. Although dermal density was also assessed, this parameter showed high inter-individual variability across the study population and showed no consistent directional change over time. Dermal thickness was therefore analysed as the primary ultrasound-derived outcome, while dermal density is reported descriptively (Section 3.2.5). On the B-scan images, dermal thickness was quantified as the vertical distance between the sub-epidermal entry echo—the upper, hyper-reflective dermal boundary—and the dermis–hypodermis interface, identified by the transition to the less echogenic subcutaneous tissue, measured perpendicular to the skin surface within the region of interest.

2.6.3. Skin Elasticity and Firmness

Skin biomechanical properties were assessed using a Cutometer® dual MPA 580 (Courage + Khazaka Electronic GmbH, Cologne, Germany). This device measures skin deformation induced by negative pressure suction (450 mbar) applied perpendicular to the skin surface. Each measurement consisted of 10 suction cycles with 2 s of suction and 2 s of relaxation. Measurements were performed on the cheek area. The following parameters

were evaluated: the F4 parameter, which reflects skin firmness as resistance to mechanical deformation, and the F0 parameter, which represents immediate skin elasticity. Lower values indicate improved skin mechanical properties.

2.6.4. Pigmentation Assessment

Skin pigmentation was evaluated using a Mexameter® MX18 (Courage + Khazaka Electronic GmbH, Cologne, Germany). The device measures melanin content by analyzing the absorption and reflection of specific wavelengths of light emitted onto the skin surface. Measurements were performed on pigmented facial areas. Lower values correspond to reduced melanin levels.

2.7. Dermatological Evaluation

A dermatologist evaluated wrinkle severity at baseline (D0), D28, and D56. Wrinkles were assessed in four facial areas: forehead, glabellar region, crow's feet, and nasolabial folds. Wrinkle severity was graded using a 0–5 clinical scale: 0 = none; 1 = perceptible; 2 = shallow; 3 = moderately deep; 4 = deep wrinkles with well-defined edges; 5 = very deep folds. This 0–5 grading was an ordinal clinical severity scale applied by the assessing dermatologist for the purposes of this study and used as a semi-quantitative descriptive tool; it does not correspond to a formally validated, published photonumeric wrinkle scale. Its scores are therefore interpreted descriptively rather than as a validated primary endpoint, and this is noted as a limitation (Section 4).

2.8. Subjective Evaluation

At the end of the study, participants completed a questionnaire evaluating cosmetic acceptability of the treatment, perceived skin improvement, ease of device use, and overall satisfaction. Participants were also asked to report any undesirable sensations or adverse events experienced during the study period.

2.9. Statistical Analysis

Statistical analyses were performed by the contract research organization (Dr. Goya Análisis S.L., **internal study code:** 2317080). Briefly, descriptive statistics including mean, standard deviation, and percentage change from baseline were calculated for each biometric parameter at D0, D28, and D56. Changes over the treatment period were evaluated by one-way analysis of variance (ANOVA) with evaluation time point (D0, D28, D56) as the factor, followed by Tukey's honestly significant difference (HSD) post-hoc test for pairwise comparisons. The p-values reported in the Results section for the D28-versus-D0 and D56-versus-D0 comparisons correspond to these ANOVA/Tukey post-hoc analyses. Because the measurements at D0, D28 and D56 were obtained from the same volunteers, this time-factor ANOVA does not fully model the within-participant correlation inherent to the longitudinal design; the original analysis has been retained, and a reanalysis using a repeated-measures or mixed-effects framework was not undertaken; the reported p-values should therefore be interpreted as exploratory (Section 4). Statistical significance was set at $p < 0.05$ (95% confidence interval). Given the exploratory nature of this study and the number of instrumental endpoints assessed, no formal correction for multiple comparisons was applied; the p-values should therefore be interpreted as descriptive, and the findings for the individual endpoints as exploratory.

For each instrumental parameter, volunteers whose measurements showed internal inconsistencies were excluded from the corresponding statistical analysis; consequently, the number of volunteers analysed varied across parameters. These exclusions were applied by the CRO during data processing on the basis of data-quality and evaluability judgements (for example, individual series incompatible with a valid instrumental acquisition).

Operationally, the excluded series comprised, in some cases, individual series that were incomplete because a measurement was missing at one time point and, in others, series judged non-evaluable on data-quality grounds; no single numerical threshold was recorded to define these cases. A formal, pre-specified numerical rule defining an "inconsistent" or "non-evaluable" measurement was not documented in the available study file; the exclusions should therefore be regarded as post-hoc quality-control decisions made during analysis rather than the application of a pre-registered criterion. The volunteers excluded per parameter, as recorded in the CRO report, were: firmness (F4), 4 (n = 16); elasticity (F0), 5 (n = 15); pigmentation (melanin index), 4 (n = 16); global wrinkle density, 4 (n = 16); forehead wrinkles, 3 (n = 17); crow's feet wrinkles, 2 (n = 18); and dermal thickness, 6 (n = 14). One volunteer (V1) was excluded from every parameter, and the remaining exclusions were distributed across different volunteers and parameters, without a pattern indicating selective removal of unfavourable values. The corresponding sample size is indicated for each parameter in the Results Section (Section 3.2). The absence of pre-specified exclusion criteria is acknowledged as a limitation (Section 4).

2.10. Use of Generative Artificial Intelligence

During the preparation of this manuscript, the author used Claude (Opus 5.5; Anthropic, San Francisco, CA, USA) in order to improve the English language and readability of the text and to assist with manuscript formatting. After using this tool, the author reviewed and edited the content as needed and takes full responsibility for the content of the publication.

3. Results

3.1. Study Population, Compliance, and Tolerability

A total of 20 female volunteers aged 40–55 years were enrolled in the study and completed the 56-day treatment period. No participant discontinued the study; however, isolated measurements considered inconsistent were excluded from the corresponding endpoint-specific analyses, as detailed in the Methods section. Treatment compliance was high, with all participants completing the scheduled treatment protocol.

Dermatological tolerability evaluation showed that the treatment was well tolerated throughout the study period. No clinically relevant adverse reactions were observed in the majority of participants. Two mild events were recorded: one case of mild xerosis, considered probably related to product use, and one case of transient mild dry-eye sensation lasting a few minutes after mask application, considered possibly related to treatment. No moderate or severe dermatological reactions were recorded, and no serious adverse events occurred during the study. Both events were mild and self-limiting and resolved spontaneously without the need for any specific treatment or medication; no participant discontinued the study or required dermatological intervention as a consequence, and treatment was continued as planned.

Subjective tolerability assessment was consistent with these findings, with 95% of volunteers reporting no undesirable sensations or symptoms following product use. A summary of the study population, compliance, and tolerability outcomes is presented in Table 1. The dermatological tolerability evaluation is illustrated in Figure 2.

Table 1. Study population characteristics, compliance, and tolerability outcomes.

Parameter	Result
Participants enrolled	20
Participants completed	20
Study discontinuations	0
Compliance with treatment protocol	100%
Serious adverse events	0
Mild xerosis (probably related)	1 participant
Transient dry-eye sensation (possibly related)	1 participant
Participants reporting no undesirable symptoms	95%

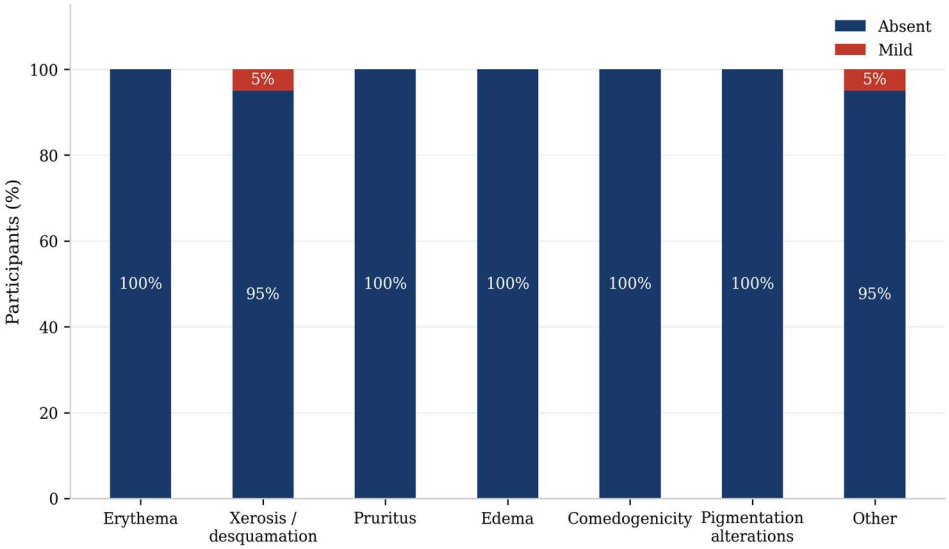


Figure 2. Dermatological tolerability assessment after 56 days of treatment (n = 20). Blue bars represent the percentage of participants with absent reactions; red bars represent mild reactions. No moderate or severe reactions were recorded during the study period.

3.2. Instrumental Evaluation

3.2.1. Skin Firmness

Skin firmness was assessed using the Cutometer dual MPA 580 by evaluating the F4 parameter, where lower values correspond to improved skin firmness. The mean F4 value decreased from 11.12 at baseline (D0) to 8.46 at D28 and 7.69 at D56, representing reductions of 23.9% and 30.8%, respectively. The reduction observed at D28 did not reach statistical significance (p = 0.1), whereas the reduction observed at D56 was statistically significant (p = 0.03). Improvement in this parameter was observed in 68.75% of participants at both D28 and D56. The evolution of the F4 parameter during the study is illustrated in Figure 3. Mean values and percentage changes for all instrumental parameters are summarized in Table 2. The number of volunteers analysed is indicated for each parameter in Table 2 (and in Section 2.9).

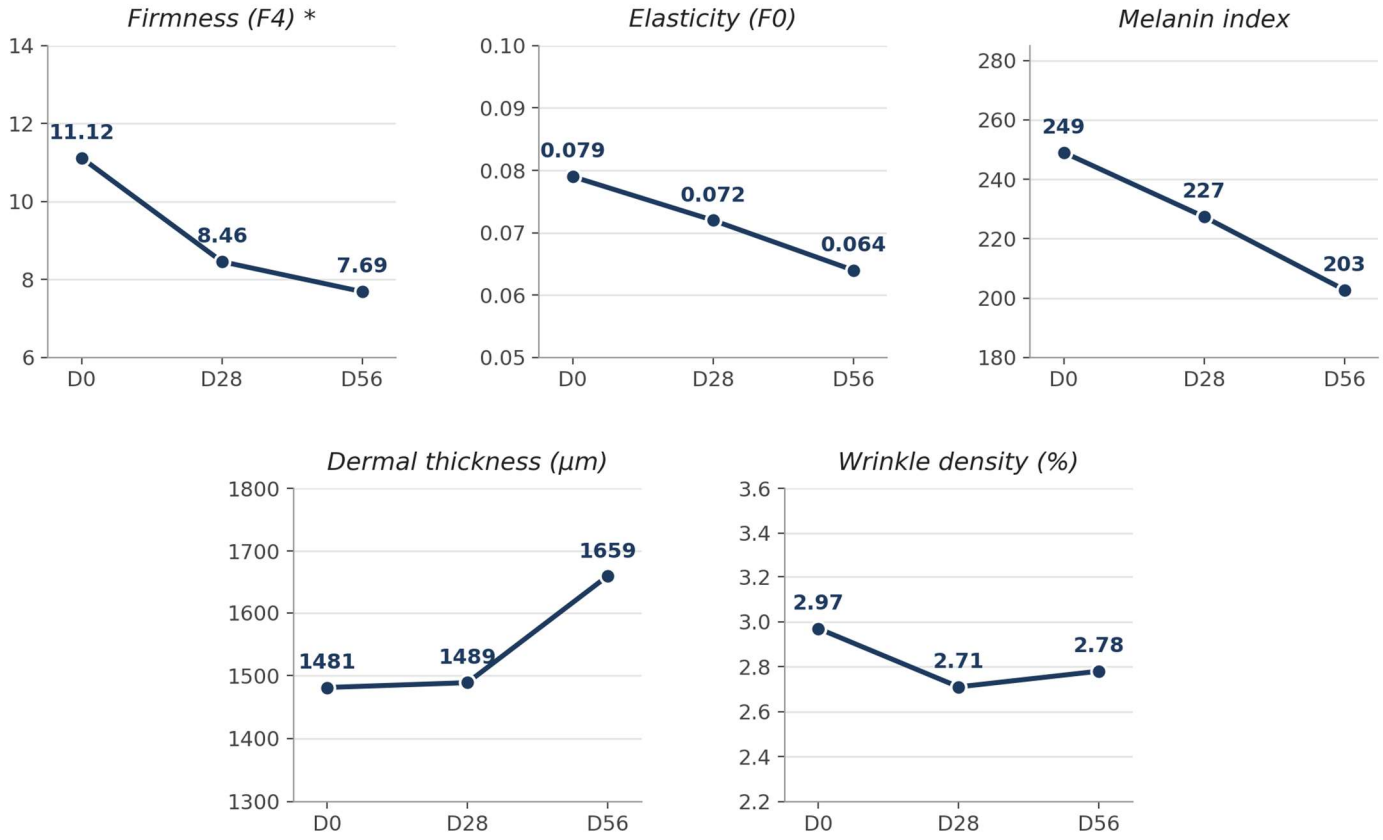


Figure 3. Evolution of instrumental skin parameters at baseline (D0), day 28 (D28), and day 56 (D56). Line charts show mean values for firmness (F4), elasticity (F0), melanin index, dermal thickness, and wrinkle density. For firmness, elasticity, melanin index and wrinkle density, lower values indicate improvement, whereas for dermal thickness higher values indicate improvement. Of these parameters, only firmness (F4) reached statistical significance at D56 (marked with an asterisk). Dermatological wrinkle severity scores are presented separately in Table 3. D0 = baseline; D28 = day 28; D56 = day 56. * $p < 0.05$ versus baseline.

Table 2. Instrumental evaluation of skin parameters at baseline (D0), D28, and D56. Values represent mean ± standard deviation (SD). D0 = baseline; D28 = day 28; D56 = day 56. * $p < 0.05$ versus baseline. Reported *p*-values are from an exploratory analysis and were not adjusted for multiple comparisons.

Parameter	*n*	D0	D28	D56	% D28	% D56	*p* D28	*p* D56
Firmness (F4)	16	11.12 ± 4.64	8.46 ± 2.78	7.69 ± 3.34	−23.9%	−30.8%	0.1	0.03 *
Elasticity (F0)	15	0.079 ± 0.018	0.072 ± 0.025	0.064 ± 0.020	−8.9%	−19.0%	0.6	0.1
Melanin index	16	249.02 ± 148.92	227.37 ± 127.74	202.77 ± 121.78	−8.7%	−18.6%	0.9	0.6
Wrinkle density (%)	16	2.97 ± 1.09	2.71 ± 1.03	2.78 ± 1.10	−6.9%	−6.4%	0.8	0.9
Forehead wrinkle number	17	49.18 ± 25.29	40.24 ± 22.88	41.53 ± 27.91	−18.2%	−15.6%	0.6	0.7
Crow's feet wrinkle number	18	10.23 ± 3.20	9.00 ± 2.89	9.67 ± 3.41	−12.0%	−5.5%	0.3	0.8
Dermal thickness (µm)	14	1481.21 ± 314.86	1488.86 ± 352.96	1658.57 ± 182.43	+0.5%	+12.0%	0.9	0.3

Table 3. Dermatological wrinkle severity scores during the study. D0 = baseline; D28 = day 28; D56 = day 56.

Region	D0	D28	D56	% Change D28	% Change D56
Forehead	3.05	2.70	2.90	−11.5%	−4.9%
Glabellar	2.50	2.20	2.20	−12.0%	−12.0%
Crow's feet	2.75	2.60	2.75	−5.5%	0%
Nasolabial folds	2.95	2.60	2.35	−11.9%	−20.3%

3.2.2. Skin Elasticity

Skin elasticity was evaluated using the F0 parameter of the Cutometer, where lower values indicate improved elasticity. The mean F0 value decreased from 0.079 at baseline to 0.072 at D28 and 0.064 at D56, indicating reductions of 8.9% and 19.0%, respectively. These variations did not reach statistical significance ($p = 0.6$ at D28; $p = 0.1$ at D56). Improvement was observed in 53.33% of volunteers at D28 and 66.67% at D56.

3.2.3. Pigmentation

Skin pigmentation was assessed using the Mexameter MX18. The mean melanin index decreased from 249.02 at baseline to 227.37 at D28 and 202.77 at D56, corresponding to reductions of 8.7% and 18.6%, respectively. These reductions were not statistically significant ($p = 0.9$ at D28; $p = 0.6$ at D56). Improvement was observed in 75% of volunteers at D28 and in 100% at D56.

3.2.4. Wrinkle-Related Topographic Parameters

Wrinkle morphology was assessed using the AEVA-HE 3D skin analysis system. For the global wrinkle parameter expressed as 3D density (%), the mean value decreased from 2.97 at baseline to 2.71 at D28 and 2.78 at D56, representing reductions of 6.9% and 6.4%, respectively. These differences were not statistically significant ($p = 0.8$ at D28; $p = 0.9$ at D56). Region-specific analysis showed similar trends. In the forehead ($n = 17$), wrinkle number decreased from 49.18 at baseline to 40.24 at D28 and 41.53 at D56, representing reductions of 18.2% and 15.6%, respectively. In the crow's feet region ($n = 18$), wrinkle number decreased from 10.23 at baseline to 9.00 at D28 and 9.67 at D56, corresponding to reductions of 12.0% and 5.5%, respectively. Representative VisioFace photographs of a study participant at baseline and after 56 days of treatment are shown in Figure 4. Representative AEVA-HE three-dimensional skin surface topography maps at baseline and D56 are shown in Figure 5.

3.2.5. Dermal Thickness and Density

Dermal structural parameters were evaluated using high-frequency ultrasound imaging (Ultrascan UC22). Mean dermal thickness increased from 1481.21 µm at baseline to 1488.86 µm at D28 and 1658.57 µm at D56, corresponding to increases of 0.5% and 12.0%, respectively. These changes did not reach statistical significance ($p = 0.9$ at D28; $p = 0.3$ at D56). Improvement was observed in 50% of volunteers at D28 and in 78.57% at D56. Dermal density, expressed in the arbitrary units provided by the device, was also assessed in the study cohort and is reported here descriptively. The number of available dermal-density measurements was $n = 19$ at D0, $n = 18$ at D28 and $n = 20$ at D56. Mean dermal density was 16.6 (D0), 15.4 (D28) and 14.5 (D56), with wide inter-individual variability (individual values ranging from approximately 10 to 27 across time points) and no consistent within-participant direction of change. No inferential test was performed for this parameter in the CRO report, and dermal density is therefore presented as descriptive

information only; its high variability limits interpretation and is consistent with the known measurement variability of this parameter. The evolution of dermal thickness during the study is illustrated in Figure 3.



Figure 4. Representative facial photographs of a study participant at baseline (D0, (**top**) row) and after 56 days of treatment (D56, (**bottom**) row), obtained with the VisioFace® 1000D system (Courage + Khazaka Electronic GmbH, Cologne, Germany). (**a**) D0 frontal view; (**b**) D0 right profile; (**c**) D0 left profile; (**d**) D56 frontal view; (**e**) D56 right profile; (**f**) D56 left profile. The eye region of the participant has been masked with an opaque bar to preserve anonymity. Written informed consent for publication was obtained from the participant. D0 = baseline; D56 = day 56.

3.3. Dermatological Evaluation

Dermatological assessment of wrinkle severity was performed in four facial regions: forehead, glabellar lines, crow's feet, and nasolabial folds. In the forehead, the mean wrinkle score decreased from 3.05 at baseline to 2.70 at D28 and 2.90 at D56, corresponding to reductions of 11.5% and 4.9%, respectively. In the glabellar region, the mean wrinkle score decreased from 2.50 at baseline to 2.20 at both D28 and D56, corresponding to a reduction of 12.0%. In the crow's feet region, the mean wrinkle score decreased from 2.75 at baseline to 2.60 at D28 but returned to baseline values at D56. In the nasolabial folds, the mean wrinkle score decreased from 2.95 at baseline to 2.60 at D28 and 2.35 at D56, corresponding to reductions of 11.9% and 20.3%, respectively. These results are summarized in Table 3.

3.4. Subjective Evaluation

Subjective evaluation indicated high levels of participant satisfaction with both the facial serum and the LED mask. For the serum, satisfaction rates ranged from 90% to 100%

for parameters related to overall opinion and cosmetic acceptability. For the LED mask, 100% of participants reported satisfaction with overall appearance, 95% with ease of use, and 85% considered the device comfortable.

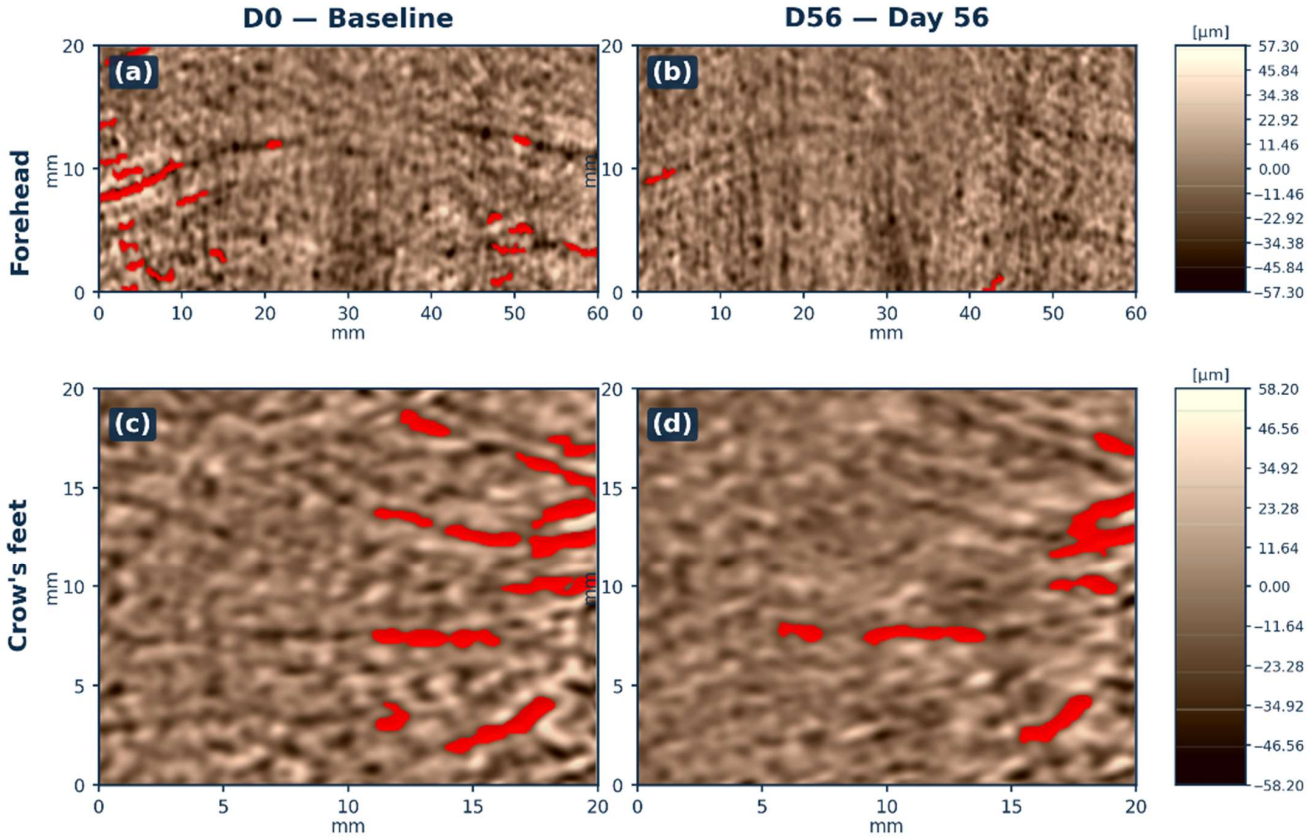


Figure 5. Representative AEVA-HE three-dimensional skin surface topography maps at baseline (D0) and after 56 days of treatment (D56) in two representative participants. Red areas indicate wrinkle objects identified by the AEVA-HE system. (**Top**) row: forehead region (Participant V11). (**Bottom**) row: crow's feet region (Participant V9). (**a**) Forehead D0; (**b**) forehead D56; (**c**) crow's feet D0; (**d**) crow's feet D56. Images obtained with the AEVA-HE 3D system (Eotech, Marcoussis, France); courtesy of Dr. Goya Análisis S.L. (CRO, Alcalá de Henares, Spain). D0 = baseline; D56 = day 56.

Perceived efficacy outcomes were also positive. At the end of the study, 90% of participants reported improvement in overall skin appearance, 90% reported improved skin tone, 85% reported increased skin comfort, and 75% reported a more rejuvenated skin appearance. A summary of subjective evaluation outcomes is presented in Table 4, and selected participant satisfaction and perceived efficacy outcomes are illustrated in Figure 6.

Table 4. Summary of subjective efficacy outcomes after 56 days.

Statement	Agreement (%)
Improved overall skin appearance	90
Improved skin tone	90
Skin feels more comfortable	85
Skin looks more rejuvenated	75
Mask easy to use	95
Mask comfortable	85
Overall satisfaction	100
Expectations met	95

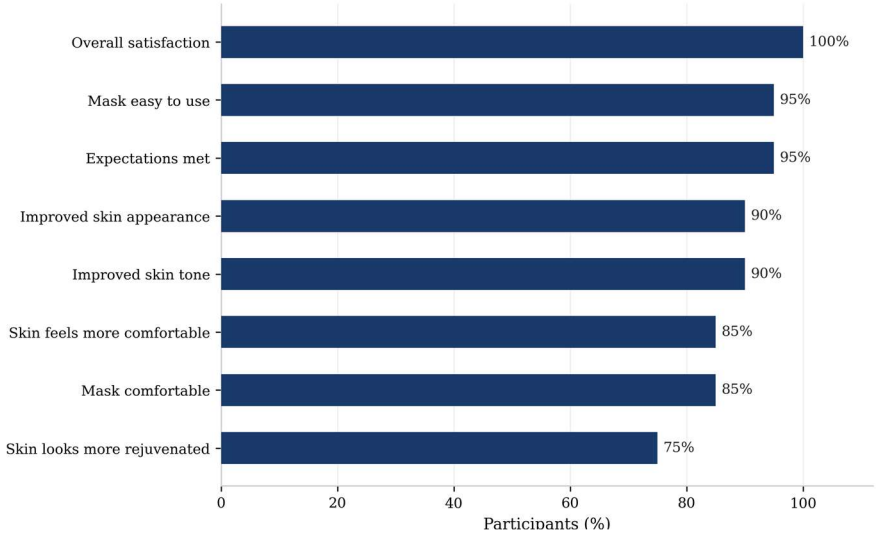


Figure 6. Participant satisfaction and perceived efficacy outcomes after 56 days of treatment (n = 20). Values represent the percentage of participants reporting agreement or satisfaction with each statement.

4. Discussion

The present study evaluated the effects of repeated use of a home-use LED photobiomodulation device, used together with a cosmetic serum as a combined regimen, on instrumental and clinical parameters associated with facial skin aging. The only endpoint that reached statistical significance was skin firmness (Cutometer F4) at D56. The remaining endpoints—elasticity, pigmentation, wrinkle-related topographic measurements and dermal thickness—showed numerical changes that did not reach statistical significance and are therefore described here as non-significant trends rather than as demonstrated improvements. These trends are compatible with, but do not by themselves establish, a biological response to repeated photobiomodulation exposure, particularly given the uncontrolled design and the concurrent use of a cosmetic serum.

The improvement in skin firmness observed in this study may be interpreted in the light of mechanisms of photobiomodulation described in previous studies. Red light has been reported to interact with mitochondrial chromophores, particularly cytochrome c oxidase, leading to enhanced ATP production, modulation of reactive oxygen species, and activation of intracellular signaling pathways involved in cellular proliferation and tissue repair. These processes have been described in previous experimental work as stimulating fibroblast activity and promoting extracellular matrix remodeling, including increased collagen synthesis and improved organization of dermal fibers. It should be emphasised, however, that these mechanisms were not assessed in the present study, which did not include any cellular, histological or biochemical measurements; fibroblast activity, collagen synthesis and matrix remodeling were therefore not measured here and are cited only as a plausible mechanistic background reported in the literature, not as effects demonstrated by our own data.

The trends toward increased dermal thickness and the changes in some wrinkle-related parameters are directionally compatible with such mechanisms; however, because these changes did not reach statistical significance, they cannot be regarded as demonstrating those effects. Notably, the parameters most closely associated with dermal biomechanical structure—firmness, elasticity and dermal thickness—showed numerical changes in a consistent direction across D0, D28 and D56; of these, however, only firmness reached statistical significance (at D56), whereas the changes in elasticity and dermal thickness did not and therefore represent non-significant trends rather than demonstrated improvements.

The statistically significant change in firmness is consistent with improvements in skin firmness reported in previous photobiomodulation studies; as dermal remodeling was not assessed here, this finding is interpreted as compatible with those reports rather than as evidence of a specific dermal mechanism, suggesting an effect that may become more pronounced with longer treatment durations. Changes in these parameters are generally gradual, and studies with larger sample sizes or extended follow-up periods may be better positioned to detect statistically significant changes in these parameters. Wrinkle-count parameters, by contrast, did not reach statistical significance and showed greater variability across timepoints, as expected for these endpoints in a small, uncontrolled sample.

The findings of the present study are in agreement with previous clinical investigations evaluating LED-based photobiomodulation for skin rejuvenation. Earlier studies have reported improvements in skin texture, elasticity, and wrinkle appearance following repeated LED treatments, and experimental research has demonstrated that red light can enhance fibroblast proliferation and collagen production [15–18]. Notably, recent studies evaluating home-use LED devices at comparable wavelengths have reported improvements in facial skin parameters after multi-week protocols [29,30], and a randomized controlled trial demonstrated a 30% reduction in periocular wrinkle volume following photobiomodulation therapy [38]. The results observed in the present study therefore align with the broader body of evidence supporting the role of photobiomodulation as a non-invasive strategy for improving skin structure and visible signs of aging.

It is also important to consider the characteristics of the device and treatment protocol. The present study evaluated a home-use LED mask designed for daily application under real-life conditions, with relatively short treatment sessions (10 min) performed twice daily. Compared with clinical-grade devices, home-use systems are designed to prioritize safety and ease of use, and biological effects may be more gradual and require sustained use to achieve measurable outcomes. Nevertheless, the high level of treatment compliance observed in this study highlights the practicality of home-use devices for long-term skincare routines, and the favorable tolerability profile supports their suitability for repeated use outside clinical settings.

Several factors may explain why some parameters did not reach statistical significance despite showing trends toward improvement. These include the relatively small sample size, inter-individual variability in skin response, and the inherent variability associated with instrumental measurements such as AEVA-HE topography and ultrasound imaging. The absence of statistically significant changes in AEVA-HE parameters is consistent with findings from previous photobiomodulation studies, where biomechanical improvements often precede detectable topographical remodeling, and where larger sample sizes are typically required to achieve statistical power for surface topography endpoints [39]. In addition, the absence of a control group limits the ability to distinguish treatment-related effects from natural temporal changes in skin condition. These considerations underscore the need for future studies incorporating larger populations, randomized controlled designs, and standardized dosimetric and measurement protocols [36,37]. The present study has several limitations that should be acknowledged: the relatively small sample size (n = 20); the absence of a placebo or untreated control group, which limits the ability to attribute observed changes exclusively to the LED treatment; the concurrent use of a cosmetic serum, which may have contributed independently to some of the observed effects; and the absence of a complete dosimetric characterization of the device within the present report, which limits direct comparison with other photobiomodulation protocols. Several further limitations should be noted. First, the inferential analysis was based on ANOVA with evaluation time as a factor followed by Tukey post-hoc comparisons; although the measurements were repeated within the same volunteers, this approach does

not fully model the within-participant correlation of the longitudinal data, and a linear mixed-effects analysis would be the more appropriate framework for a confirmatory study. Combined with the small sample and the number of endpoints assessed without correction for multiple comparisons, this reinforces the exploratory status of all p-values reported here. Second, the exclusion of individual measurement series considered inconsistent or non-evaluable was performed by the CRO as a post-hoc data-quality step and was not governed by a pre-specified, documented numerical criterion, which introduces a potential source of bias, mitigated only in part by the observation that the exclusions did not follow a pattern favouring significant results. Third, although the device was characterised by spectroradiometry (confirming the red and near-infrared bands and their relative optical contribution), this measurement expressed radiant flux rather than per-wavelength irradiance in mW/cm^2, did not resolve the individual near-infrared bands separately, and did not cover the nominal 1072 nm band, which lay above the instrument range. Fourth, the dermatological wrinkle assessment used an ordinal 0–5 clinical grading applied by the assessing dermatologist rather than a formally validated photonumeric scale, so those scores are descriptive. These limitations should be weighed when interpreting the findings, which remain preliminary and hypothesis-generating.

The combined use of the LED device with a standardized cosmetic serum may also have contributed to the observed effects. Although this reflects real-world usage conditions and was applied consistently across all participants, it limits the ability to isolate the specific contribution of photobiomodulation. Future studies comparing LED treatment alone versus combined regimens would help clarify the relative impact of each component.

The contemporary evidence base has continued to expand. Recent systematic reviews and narrative overviews have summarised the growing use of LED photobiomodulation in cosmetic dermatology and its transition from professional systems to home-use consumer devices [33–35]. Consistent with the present findings, a 2025 multicentre, randomized, double-blind, sham-controlled study of a home-use LED/IRED mask reported improvement in crow's feet over 16 weeks [40], whereas a 2024 study of a home-use under-eye device reported high user satisfaction but no statistically significant objective change in wrinkle score [41], illustrating the continued need for adequately powered, controlled studies.

Overall, in this uncontrolled study the combined LED-plus-serum regimen was associated with a statistically significant improvement in skin firmness, whereas the remaining instrumental endpoints showed only non-significant numerical trends. These preliminary findings are compatible with previously reported effects of photobiomodulation but, given the absence of a control group and the concurrent use of a cosmetic serum, do not establish the independent efficacy of the LED device. These findings should be interpreted within the context of the study's sample size and single-centre design, and further research is warranted to optimize treatment protocols and better characterize long-term outcomes.

5. Conclusions

The present study evaluated the effects of repeated use of a home-use LED photobiomodulation device on instrumental and clinical parameters associated with facial skin aging. The treatment was well tolerated, with high participant compliance and no serious adverse events reported, indicating a favorable dermatological safety profile.

A statistically significant improvement in skin firmness was observed after 56 days of the combined regimen (LED mask plus cosmetic serum), which may be consistent with the known effects of photobiomodulation on fibroblast activity and extracellular matrix remodeling described in previous studies, although these mechanisms were not directly assessed here. Additional parameters—including dermal thickness, pigmentation, and

wrinkle-related measurements—showed only non-significant numerical trends and should not be interpreted as demonstrated improvements. These findings align with previously reported outcomes of LED-based photobiomodulation in aesthetic dermatology.

Overall, and taking into account that the study was uncontrolled and evaluated the LED device combined with a cosmetic serum, the present results should be regarded as preliminary. They suggest that a skincare regimen incorporating repeated use of a home-use LED photobiomodulation device together with a cosmetic serum may be associated with an improvement in skin firmness, but the independent efficacy of the LED device cannot be established from this study. Further studies involving larger populations, longer treatment durations, and controlled comparative designs (including LED alone versus LED plus serum and versus untreated or sham control) are warranted to better characterize long-term effects and optimize treatment protocols for home-use photobiomodulation devices.

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Institutional Review Board Statement: This study was not subject to formal ethics committee/IRB approval, as it was an efficacy study of a cosmetic product not requiring such review under applicable regulations. Specifically, the investigation was a non-invasive cosmetic efficacy, tolerability and acceptability evaluation of a finished cosmetic regimen under normal conditions of use in healthy adult volunteers; it did not involve a medicinal product, an investigational medical device, or invasive procedures and therefore did not constitute a clinical trial or a clinical investigation requiring approval by a research ethics committee under the applicable European and Spanish frameworks. It was conducted under dermatological supervision by an independent contract research organization (Dr. Goya Análisis S.L.; internal study code: 2317080). All participants received information concerning the study procedures and provided written informed consent prior to participation. Participant confidentiality was protected, and adverse events were monitored throughout the study.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study. Written informed consent for the publication of identifiable facial photographs has been obtained from the participant whose images are presented in Figure 4.

Data Availability Statement: The data presented in this study are available on request from the corresponding author due to privacy and ethical restrictions related to the clinical study protocol.

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Conflicts of Interest: The author declares a dual affiliation: she is a researcher at Universidad Internacional de La Rioja (UNIR) and is also affiliated with Femtechnology (Spain), the company that funded this study and manufactures the device evaluated. The sponsor was involved in the study design and provided the products used; however, clinical data collection and instrumental assessments were performed by an independent contract research organization (Dr. Goya Análisis S.L., Spain). Statistical analyses reported in the CRO study report were used for interpretation in the present manuscript. To further clarify the roles: the sponsor (Femtechnology) designed the study and supplied the products; the independent CRO (Dr. Goya Análisis S.L.) recruited participants, acquired the instrumental data and conducted the statistical analyses; and the author accessed the resulting dataset and the CRO report to prepare the manuscript. The funders had no role in the writing of the manuscript or in the decision to publish the results.

References

1. American Society of Plastic Surgeons. Plastic Surgery Statistics Report 2024. Available online: https://www.plasticsurgery.org/news/plastic-surgery-statistics (accessed on 10 June 2026).

2. International Society of Aesthetic Plastic Surgery (ISAPS). ISAPS Global Survey Results 2022. Available online: https://www.isaps.org/discover/about-isaps/global-statistics/global-survey-2022-full-report-and-press-releases/ (accessed on 25 May 2026).
3. American Society of Plastic Surgeons. Plastic Surgery Statistics. Available online: https://www.plasticsurgery.org/plastic-surgery-statistics (accessed on 2 June 2026).
4. Avci, P.; Gupta, A.; Sadasivam, M.; Vecchio, D.; Pam, Z.; Pam, N.; Hamblin, M.R. Low-level laser (light) therapy (LLLT) in skin: Stimulating, healing, restoring. *Semin. Cutan. Med. Surg.* **2013**, *32*, 41–52.
5. Jagdeo, J.; Adams, L.; Brody, N.; Siegel, D.M. Transcranial red and near infrared light transmission in a cadaveric model. *PLoS ONE* **2012**, *7*, e47460. [CrossRef]
6. Chung, H.; Dai, T.; Sharma, S.K.; Huang, Y.Y.; Carroll, J.D.; Hamblin, M.R. The nuts and bolts of low-level laser therapy. *Ann. Biomed. Eng.* **2012**, *40*, 516–533. [CrossRef]
7. Hamblin, M.R. Mechanisms and applications of the anti-inflammatory effects of photobiomodulation. *AIMS Biophys.* **2017**, *4*, 337–361. [CrossRef]
8. Karu, T.I. Mitochondrial mechanisms of photobiomodulation in context of new data about multiple roles of ATP. *Photomed. Laser Surg.* **2010**, *28*, 159–160. [CrossRef]
9. Barolet, D. Light-emitting diodes (LEDs) in dermatology. *Semin. Cutan. Med. Surg.* **2008**, *27*, 227–238. [CrossRef]
10. Lee, S.Y.; Park, K.H.; Choi, J.W.; Kwon, J.K.; Lee, D.R.; Shin, M.S.; Lee, J.S.; You, C.E.; Park, M.Y. A prospective, randomized, placebo-controlled, double-blinded, and split-face clinical study on LED phototherapy for skin rejuvenation: Clinical, profilometric, histologic, ultrastructural, and biochemical evaluations and comparison of three different treatment settings. *J. Photochem. Photobiol. B* **2007**, *88*, 51–67. [CrossRef]
11. Calderhead, R.G.; Vasily, D.B. Low level light therapy with light-emitting diodes for the aging face. *Clin. Plast. Surg.* **2016**, *43*, 541–550. [CrossRef]
12. Goldberg, D.J.; Russell, B.A. Combination blue (415 nm) and red (633 nm) LED phototherapy in the treatment of mild to severe acne vulgaris. *J. Cosmet. Laser Ther.* **2006**, *8*, 71–75. [CrossRef]
13. Jagdeo, J.; Austin, E.; Mamalis, A.; Wong, C.; Ho, D.; Siegel, D.M. Light-emitting diodes in dermatology: A systematic review of randomized controlled trials. *Lasers Surg. Med.* **2018**, *50*, 613–628. [CrossRef]
14. Wunsch, A.; Matuschka, K. A controlled trial to determine the efficacy of red and near-infrared light treatment in patient satisfaction, reduction of fine lines, wrinkles, skin roughness, and intradermal collagen density increase. *Photomed. Laser Surg.* **2014**, *32*, 93–100. [CrossRef]
15. Russell, B.A.; Kellett, N.; Reilly, L.R. A study to determine the efficacy of combination LED light therapy (633 nm and 830 nm) in facial skin rejuvenation. *J. Cosmet. Laser Ther.* **2005**, *7*, 196–200. [CrossRef]
16. Barolet, D.; Christiaens, F.; Hamblin, M.R. Infrared and skin: Friend or foe. *J. Photochem. Photobiol. B* **2016**, *155*, 78–85. [CrossRef]
17. Couturaud, V.; Le Fur, M.; Pelletier, M.; Granotier, F. Reverse skin aging signs by red light photobiomodulation. *Skin. Res. Technol.* **2023**, *29*, e13391. [CrossRef]
18. Hamblin, M.R.; Demidova, T.N. Mechanisms of low level light therapy. *Proc. SPIE* **2006**, *6140*, 614001. [CrossRef]
19. Sorbellini, E.; Rucco, M.; Rinaldi, F. Photodynamic and photobiological effects of light-emitting diode (LED) therapy in dermatological disease: An update. *Lasers Med. Sci.* **2018**, *33*, 1431–1439. [CrossRef]
20. Taniguchi, Y.; Ohshiro, T.; Ohshiro, T.; Sasaki, K.; Fujii, S. Clinical experience with 630 nm light-emitting diode (LED) photomodulation for sun-induced aging or environmentally damaged skin. *Laser Ther.* **2007**, *16*, 137–141. [CrossRef]
21. Huang, A.; Nguyen, J.; Ho, D.; Jagdeo, J. Light emitting diode phototherapy for skin aging. *J. Drugs Dermatol.* **2020**, *19*, 359–364. [CrossRef]
22. Fisher, G.J.; Kang, S.; Varani, J.; Bata-Csorgo, Z.; Wan, Y.; Datta, S.; Voorhees, J.J. Mechanisms of photoaging and chronological skin aging. *Arch. Dermatol.* **2002**, *138*, 1462–1470. [CrossRef]
23. Mineroff, J.; Austin, E.; Jagdeo, J. Cutaneous effects of photobiomodulation with 1072 nm light. *Arch. Dermatol. Res.* **2022**, *315*, 1481–1486. [CrossRef]
24. Shin, J.W.; Kwon, S.H.; Choi, J.Y.; Na, J.I.; Huh, C.H.; Choi, H.R.; Park, K.C. Molecular mechanisms of dermal aging and antiaging approaches. *Int. J. Mol. Sci.* **2019**, *20*, 2126. [CrossRef]
25. Glass, G.E. Photobiomodulation: The clinical applications of low-level light therapy. *Aesthet. Surg. J.* **2021**, *41*, 723–738. [CrossRef]
26. Bragato, E.F.; Pires, J.A.; Momolli, M.; Guerra, M.B.; Paisano, A.F.; Ferrari, R.A.M.; Bussadori, S.K.; Motta, L.J. Comparison of the effects of 2 frequencies of application of photobiomodulation on facial rejuvenation: Controlled, randomized, and double-blind clinical trial. *Medicine* **2023**, *102*, e32514. [CrossRef]
27. Mineroff, J.; Maghfour, J.; Ozog, D.M.; Lim, H.W.; Kohli, I.; Jagdeo, J. Photobiomodulation CME part II: Clinical applications in dermatology. *J. Am. Acad. Dermatol.* **2024**, *91*, 805–815. [CrossRef]

28. Kim, D.S.; Song, K.U.; Lee, H.K.; Park, J.H.; Kim, B.J.; Yoo, K.H.; Shin, J.H. Synergistic effects of using novel home-use 660- and 850-nm light-emitting diode mask in combination with hyaluronic acid ampoule on photoaged Asian skin: A prospective, controlled study. *J. Cosmet. Dermatol.* **2020**, *19*, 2606–2615. [CrossRef]
29. Ng, J.N.C.; Wanitphakdeedecha, R.; Yan, C. Efficacy of home-use light-emitting diode device at 637 and 854 nm for facial rejuvenation: A split-face pilot study. *J. Cosmet. Dermatol.* **2020**, *19*, 2288–2294. [CrossRef]
30. Guermonprez, C.; Declercq, L.; Decaux, G.; Grimaud, J.-A. Safety and efficacy of a novel home-use device for light-potentiated (LED) skin treatment. *J. Biophotonics* **2020**, *13*, e202000230. [CrossRef]
31. Luebberding, S.; Krueger, N.; Kerscher, M. Skin physiology in men and women: In vivo evaluation of 300 people including TEWL, SC hydration, sebum content and skin surface pH. *Int. J. Cosmet. Sci.* **2013**, *35*, 477–483. [CrossRef]
32. Dobrev, H. Use of Cutometer to assess epidermal hydration. *Skin. Res. Technol.* **2000**, *6*, 239–244. [CrossRef]
33. Ngoc, L.T.N.; Moon, J.-Y.; Lee, Y.-C. Utilization of light-emitting diodes for skin therapy: Systematic review and meta-analysis. *Photodermatol. Photoimmunol. Photomed.* **2023**, *39*, 303–317. [CrossRef]
34. Koperdowska, J.M.; Broen, J.A. Light-emitting diode photobiomodulation in dermatology: From professional systems to consumer devices—Mechanisms, efficacy and safety. *Forum Dermatol.* **2026**, *12*, e05026036. [CrossRef]
35. Guo, Z.; Yuan, K. The application of light-emitting diode (LED) in cosmetic dermatology. *Photodermatol. Photoimmunol. Photomed.* **2025**, *41*, e70041. [CrossRef]
36. Zein, R.; Selting, W.; Hamblin, M.R. Review of light parameters and photobiomodulation efficacy: Dive into complexity. *J. Biomed. Opt.* **2018**, *23*, 120901. [CrossRef]
37. Gavish, L.; Houreld, N.N. Therapeutic efficacy of home-use photobiomodulation devices: A Systematic Literature Review. *Photobiomodul. Photomed. Laser Surg.* **2019**, *37*, 4–16. [CrossRef]
38. Mota, L.R.; Duarte, I.S.; Galache, T.R.; Pretti, K.M.S.; Chiarelli Neto, O.; Motta, L.J.; Horliana, A.C.R.T.; da Silva, D.F.T.; Pavani, C. Photobiomodulation reduces periocular wrinkle volume by 30%: A randomized controlled trial. *Photobiomodul. Photomed. Laser Surg.* **2023**, *41*, 48–56. [CrossRef]
39. Lagarde, J.M.; Rouvrais, C.; Black, D.; Diridollou, S.; Gall, Y. Skin topography measurement by interference fringe projection: A technical validation. *Skin Res. Technol.* **2001**, *7*, 112–121. [CrossRef]
40. Park, S.H.; Park, S.O.; Jung, J.-A. Clinical study to evaluate the efficacy and safety of home-used LED and IRED mask for crow's feet: A multi-center, randomized, double-blind, sham-controlled study. *Medicine* **2025**, *104*, e41596. [CrossRef]
41. Wang, J.Y.; Kabakova, M.; Patel, P.; Bitterman, D.; Zafar, K.; Philip, R.; Gollogly, J.M.; Rivas, S.; Kurtti, A.; Yousefi, N.; et al. Outstanding user reported satisfaction for light-emitting diodes under-eye rejuvenation. *Arch. Dermatol. Res.* **2024**, *316*, 511. [CrossRef]

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