Photodiagnosis and Photodynamic Therapy 28 (2019) 195–200

Contents lists available at ScienceDirect

Photodiagnosis and Photodynamic Therapy

journal homepage: www.elsevier.com/locate/pdpdt

Application of superluminescent diodes (sLED) in the treatment of scarring alopecia – A pilot study

Agnieszka Gerkowicz[a,*], Joanna Bartosińska[a], Katarzyna Wolska-Gawron[a], Małgorzata Michalska-Jakubus[a], Mirosław Kwaśny[b], Dorota Krasowska[a]

[a] Department of Dermatology, Venereology and Pediatric Dermatology, Medical University of Lublin, Staszica 16 St., 20-081 Lublin, Poland
[b] Institute of Optoelectronics, The Military University of Technology, Kaliskiego 2 St., 01-476 Warsaw, Poland

ARTICLE INFO

Keywords:
Frontal fibrosing alopecia
Lichen planopilaris
LED therapy

ABSTRACT

Introduction: Photobiomodulation therapy with the use of light-emitting diodes (LEDs) is a fast growing therapeutic technique with a wide range of dermatologic indications. Recently it has been suggested that LED therapy could be beneficial in scarring alopecia.

Aim: Assessment of the efficacy of novel superluminescent diodes (sLED) with a "soft- start" as an adjuvant treatment in selected types of scarring alopecia.

Methods: This pilot study included 16 female patients: 8 with frontal fibrosing alopecia (FFA) and 8 with lichen planopilaris (LPP), aged 41–76 years with a stable treatment, either topical or systemic. In all patients, sLED irradiations were performed once a week for a 10-week period. The sLEDs' effectiveness was assessed clinically and using trichoscopy.

Results: The therapy was well tolerated. Both Lichen Planopilaris Activity Index (LPPAI) and Frontal Fibrosing Alopecia Severity Score (FFASS) were significantly reduced after the therapy ($p = 0.012$, $p = 0.017$ respectively). Within the treated area, the number of thick hairs significantly increased after the therapy ($p = 0.009$), whereas the number of medium-sized hairs and thin hairs did not change significantly ($p = 0.836$, $p = 0.675$ respectively).

Conclusions: Irradiations with sLEDs were demonstrated to be safe and well tolerated. This noninvasive therapy leads to the reduction of subjective symptoms, and improve the outcome both in FFA and in LPP. This effective novel light source can be used as an adjuvant therapy in patients with chronic LPP or FFA. However, further studies including a larger study group and a control group are needed to evaluate the long-term effects of the therapy.

1. Introduction

Photobiomodulation therapy, also known as low level laser (light) therapy (LLLT), is fast gaining popularity as a therapeutic technique. According to the consensus, it is defined as a form of light therapy that utilizes non-ionizing forms of light sources, including lasers, light-emitting diodes (LEDs) and broadband light, in the red or near-infrared spectrum with the most effective wavelengths in the range of 600–700 nm [1–3]. Among all those light sources, LEDs seem to be more advantageous in dermatology, since they provide non-ablative, non-thermal irradiation of a relatively large area [4]. Possible mechanisms of action include: stimulation of angiogenesis, modulation of oxidative stress, increased adenosine triphosphate (ATP) production, alteration of collagen synthesis [4,5]. One of the most important clinical applications of LEDs is photodynamic therapy (PDT) [5]. Recently, new superluminescent diodes (sLED) with a "soft start" were demonstrated to be an effective novel light source in PDT [6].

LEDs have been applied across a broad range of indications, including pre-cancerous and cancerous skin lesions, as well as acne vulgaris, rosacea, psoriasis, skin rejuvenation and hair loss [4,5]. Most data reporting the efficacy of LLLT therapy for the treatment of hair loss consider androgenetic alopecia. Usually, the devices applied in those studies used lasers or a combination of LEDs and lasers with the most commonly used wavelengths ranging from 635 to 650 nm [5,4,7]. The data considering use of LEDs in scarring alopecia are scarce. To the best of our knowledge, so far the effectiveness of LED therapy in LPP was only demonstrated in one study [8]. Considering the promising results of this study, it was suggested that LED therapy could be beneficial in

* Corresponding author.
E-mail address: agerkowicz@wp.pl (A. Gerkowicz).

https://doi.org/10.1016/j.pdpdt.2019.09.006
Received 15 January 2019; Received in revised form 8 September 2019; Accepted 19 September 2019
Available online 20 September 2019

scarring alopecia [5,8].

2. Aims

The aim of the study was to assess the efficacy of superluminescent diodes (sLED) with a "soft-start" as an adjuvant treatment of selected types of scarring alopecia.

3. Methods

3.1. Study group

This pilot study included 16 female patients: 8 with frontal fibrosing alopecia (FFA) and 8 with lichen planopilaris (LPP), aged 41–76 years (average age 60.1 ± 9.6 years). In all patients, diagnosis was confirmed based on clinical presentation, trichoscopic pattern and histopathological examination. Inclusion criteria were: disease duration of at least 1.5 years and stable treatment (either topical or systemic) for six months. During the study, the previous treatment was not modified and patients continued it. Exclusion criteria included: age < 18 years, non-scarring alopecia, scarring alopecia different than FFA or LPP, pregnancy, breast feeding, lack of stable treatment, epilepsy. The therapy was not performed during summer. Written informed consent was obtained from all patients before enrolment to the study. The study was approved by the Local Ethics Committee (KE-0254/167/2017).

3.2. Irradiation of the scalp with superluminescent diodes (sLED) with "soft start"

In all patients, the sLED therapy was performed using a source of light based on the superluminescent LED matrix illuminator: Red Beam Pro + (MedLight GmbH). This lamp contains three movable units with 78 high power red light-emitting diodes of the latest generation so-called superluminescent which provide pulsed red light operating at 630 ± 5 nm with a maximum power density of 100–120 mW/cm2 (Fig. 1) [9]. This lamp works with a "soft start", which means that irradiation increases gradually from 40 to 100% of the maximum power of illumination during the first 4 min. Each treatment session lasted 13 min and 47 s in the pulse mode. A single pulse duration was 430 ms with 130 ms intervals. The dose per session was 44.45 J/cm^2 and light power density of 70 mW/cm^2. The distance from the scalp was 15 cm. Sessions were performed once a week for a period of 10 weeks.

3.3. Assessment of the sLEDs' effectiveness

To determine the effects of sLED therapy, a trichoscopic examination was performed according to standard procedure with 20x and 70x magnification using the FotoFinder Dermoscope in all patients before and after 10 sessions. Then, within the treated area, 2 specific fields were selected to assess the number of hairs according to hair thickness before and after 10 irradiations. To obtain repeatability, the localisation was marked using videodermatoscopy mapping and in each patient the distance from middle line to the selected localisation was measured using a medical tape measure. In patients with FFA the evaluation was performed 1–5 cm from the midline within the frontal hairline and in LPP 1–5 cm from the midline within the parietal area. Hair thickness was measured in two fields at 70x magnification (each field corresponds to 9 mm^2).

The hairs were divided into 3 groups: thick hairs > 0.05 mm, medium-sized hairs 0.03–0.05 mm and thin hairs < 0.03 mm. To assess inflammation within the treated area, a trichoscopic evaluation of perifollicular hyperkeratosis and erythema was performed. The severity was classified as none, mild, moderate or severe before and after therapy. Itching, burning sensation and pain were assessed by the patients based on a 10-point visual analogue scale at the beginning and at the end of therapy. In patients with LPP, disease activity was assessed using the Lichen Planopilaris Activity Index (LPPAI) with a score of 0–10 [10], and in patients with FFA using the Frontal Fibrosing Alopecia Severity Score (FFASS) based on the protocol proposed by Saceda-Corallo et al. with a score of 0–25, with a small modification: the severity of perifollicular erythema and hyperkeratosis was evaluated using trichoscopy [11]. The primary end point was the change of the number of thick, medium-sized and thin hairs after 10 weeks within 2 evaluated fields. The secondary end point was patients' assessment of

Fig. 1. View of sLED matrix illuminator.

subjective symptoms.

3.4. Statistical analysis

The data were statistically analysed using SAS software. We estimated the lower quartile (Q1), upper quartile (Q3), median (Me) and interquartile range (IR) for continuous variables, as well as absolute numbers (n) and percentages (%) of the occurrence of items for categorical variables.

We used the Wilcoxon signed-rank test to compare the number of hairs, severity of symptoms and two indexes (LPPAI and FFASS) before and after treatment, as well as Fisher's exact test to compare severity of perifollicular hypekeratosis and erythema before and after treatment.

The significance level was assumed at 0.05.

4. Results

In the study group, 8 (50%) patients had LPP, and 8 (50%) FFA. The disease had lasted for 1.5–12 years, 3.0 years on average. During the study, all participants continued their previous therapy. 5 (31.25%) patients received only topical therapy (including moderate to potent topical steroids), 2 (12.5%) received only systemic therapy (hydroxychloroquine 200 mg once daily) and 9 (56.25%) patients were treated with both topical and systemic medications including a combination of moderate to potent topical steroids with hydroxychloroquine 200 mg twice a day (8 patients) or finasteride 5 mg/day (1 patient).

In the treated area, the total number of hairs was 29.55 on average before treatment and increased after treatment up to 48.05 on average; however, the difference was not statistically significant ($p = 0.079$). The number of thick hairs significantly increased after the therapy ($p = 0.009$) from 23.0 on average before treatment to 37.0 on average after treatment, whereas the number of medium-sized hairs and thin hairs did not change significantly ($p = 0.836$ and $p = 0.675$ respectively). Results are shown in Table 1 and Fig. 2.

Both LPPAI and FFASS were significantly reduced after treatment ($p = 0.012$ and $p = 0.017$ respectively). LPPAI before treatment was 4.66 on average and 1.33 on average after treatment. FFASS after treatment was reduced in almost all patients (except one, in whom it remained the same). The results are shown in Table 2.

Severity of inflammation characterized by perifollicular hyperkeratosis decreased significantly in the study group ($p = 0.009$, Table 3). In all patients with the most severe perifollicular hyperkeratosis (5 patients) sLED therapy resulted in clinical improvement: the post-treatment severity of perifollicular hyperkeratosis was assessed as mild. In six patients with mild severity before treatment, 5 patients presented with no perifollicular hyperkeratosis after treatment, whereas in 1 patient the perifollicular hyperkeratosis remained unchanged. Only one patient developed exacerbation characterized by an increase of perifollicular hyperkeratosis from moderate to severe. In the remaining 3 patients with moderate perifollicular hyperkeratosis its severity remained unchanged in 1 patient and the symptom resolved completely in 1 patient. Perifollicular erythema did not exhibit a statistically significant change ($p = 0.135$, Table 4). As in the case of perifollicular hyperkeratosis, the most prominent reduction of erythema was observed in more severe stages. Among 5 patients with severe perifollicular erythema, after the treatment 2 patients had moderate and 3 mild perifollicular erythema. In 9 patients with moderate perifollicular erythema, the post-treatment severity was assessed as moderate in 1 and mild in 4 patients. In the remaining 4 patients, perifollicular erythema disappeared. In two patients with mild perifollicular erythema at the beginning, at the end of the study its severity was assessed as "none". All subjects tolerated the therapy well. All patients had significant reductions in itching ($p < 0.001$), burning sensation ($p = 0.001$) and pain ($p = 0.008$). The results are shown in Table 5. The severity of itching was 5.5 on average before treatment and decreased to 1.0 after treatment. The severity of the burning sensation was 3.0 on average before treatment and decreased to 0.0 on average after treatment. The severity of pain was 1.5 on average before treatment and decreased to 0.0 on average after treatment.

During the irradiation, patients reported pleasant warmth, and some of them reported a stinging sensation. 2–3 days after irradiation, skin dryness was observed in 4 patients. Subjects with the most severe lesions reported faster reduction of the symptoms.

5. Discussion

The attempts to use LED as light sources started in the early 1990s. Initially, single LEDs offered very low power of a few mW, which significantly limited their use. With the recent developments in high-power light emitting diodes so-called superluminescent, sLEDs have been used as an alternative light source for PDT. The power of a single so-called superluminescent LED (sLED) is approx. 50–100 mW (even up to 1 W for some wavelengths) [9,12,13]. The use of sLED enabled the construction of compact, economical and stable illuminators [9,13,14].

In our study, we evaluated for the first time the effect of superluminescent LEDs with a "soft start" on FFA and LPP. The main advantage of this lamp is the use of sLEDs, a light source characterized by high efficiency of light emission, low time coherence and high spatial coherence. Therefore, they share the advantages of both laser and LED devices [13].

To the best of our knowledge, so far there is only a single study that evaluated LED therapy in 8 patients with LPP [8] and there are no studies that evaluated LED therapy in FFA. It is still discussed whether FFA is a clinical variant of LPP [15] or whether those two diseases are distinct entities [16]. Recently it has been suggested that FFA and LPP are two phenotypically distinct branches of the same pathobiology tree [16]. The results obtained in our study suggest that treatment with sLEDs could be beneficial in the treatment of scarring alopecia both in LPP and FFA. Despite significant reduction of both LPPAI and FFASS indexes, patients with LPP responded faster and better to the treatment. The lower reduction of the FFASS index may result from the fact that unlike the LPPAI index, FFASS includes hairline recession as a main parameter. Therefore, to eliminate the possible differences caused by those two assessment tools in our study, the same trichoscopic parameters and subjective symptoms were evaluated in all patients. Regardless of the type of scarring alopecia, the subjective symptoms such as itching, pain and burning sensations significantly decreased in all participants after the irradiation. Considering previous reports, itching,

Table 1
Comparison of the number of thick, medium-sized and thin hairs and the total number of hairs before and after treatment within 2 assessed fields. (N = 16).

Hair thickness	Before treatment						After treatment						Statistical test	
	Min	Max	Q1	Me	Q3	IR	Min	Max	Q1	Me	Q3	IR	Z	p
Thin < 0,03mm	0	3	0.0	0.0	1.5	1.5	0	2	0.0	0.0	1.0	1.0	0.419	0.675
Medium 0,03–0,05mm	3	16	6.5	8.0	14.5	8.0	4	35	5.5	8.5	13.0	7.5	0.207	0.836
Thick > 0,05mm	11	49	15.5	23.0	31.5	16.0	12	52	17.5	37.0	42.5	25.0	2.605	**0.009**
Total	18	66	26.5	29.5	43.0	16.5	20	87	26.0	48.0	53.5	27.5	1.758	0.079

Me – median, Q1 – lower quartile, Q2 – upper quartile, IR – interquartile range.

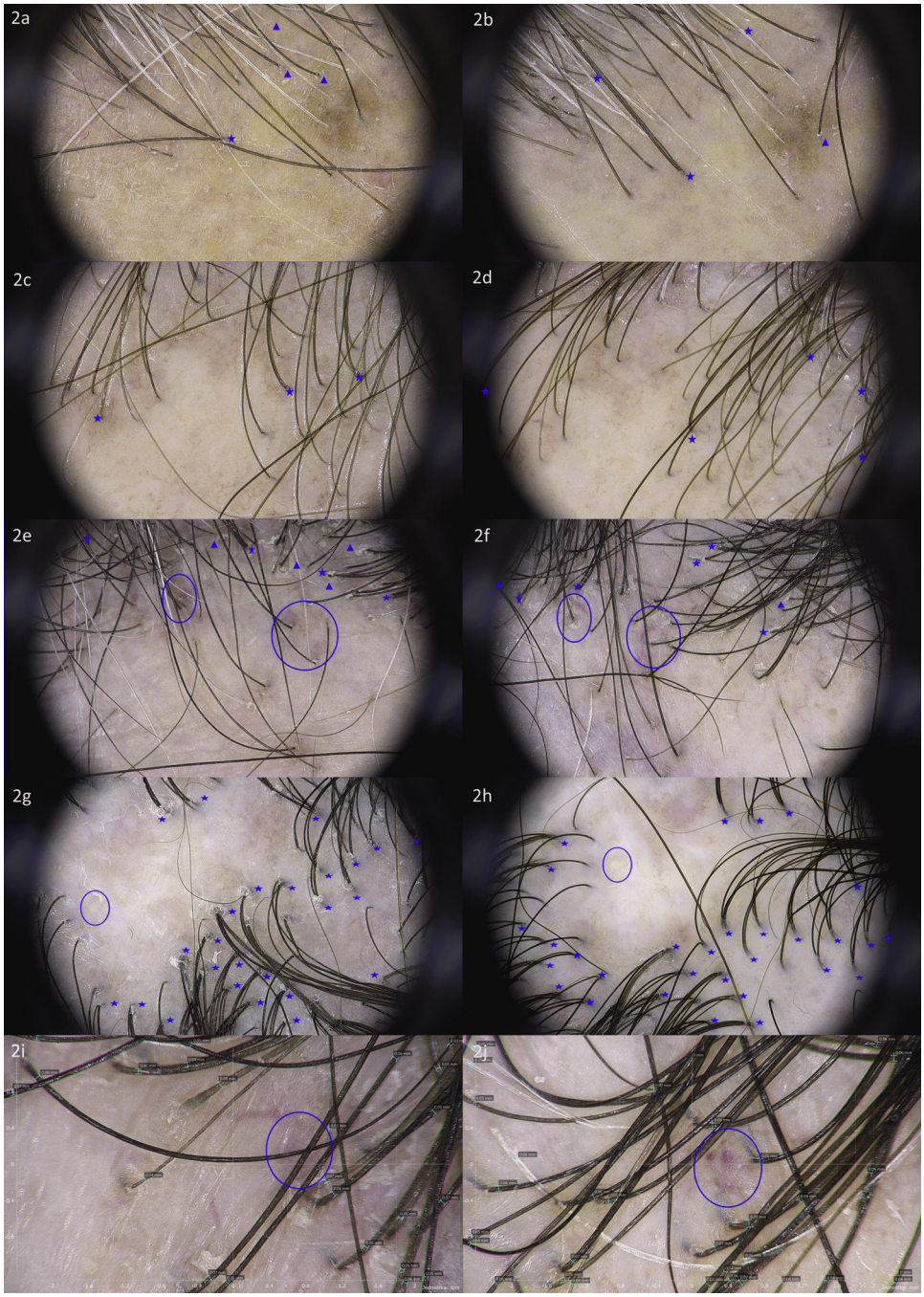

Fig. 2. Trichoscopic images of patients with FFA and LPP; FFA – frontal fibrosing alopecia, LPP- lichen planopilaris, ▲ – perifollicular hyperkeratosis, ★ – follicular units with > 1 hair.
(2a, 2c, 2e,): FFA pretreatment trichoscopic images (20x, without immersion fluid); (2b, 2d, 2f): FFA posttreatment trichoscopic images after treatment (20x, without immersion fluid); (2a): mild perfollicular hyperkeratosis, total hair number n = 44, follicular units with > 1 hair n = 1; (2b): reduction of perifollicular hyperkeratosis, total hair number n = 55, follicular units with > 1 hair n = 3; (2c): total hair number n = 51, follicular units with > 1 hair n = 3; (2d): total hair number n = 67, increased number of follicular units with > 1 hair n = 5; (2e-f): characteristic for this localisation pattern of blood vessels (blue ring), (2e): moderate perifollicular hyperkeratosis, follicular units with > 1 hair n = 4, (2f): mild perifollicular hyperkeratosis, increased hair number in the frontal hair line, follicular units with > 1 hair n = 6, within the scarring area visible lost of some hair follicles; (2 g, 2i): LPP pretreatment trichoscopic images; (2 h, 2 j): LPP posttreatment trichoscopic images; (2 g–h): scar after skin biopsy (blue ring), (2 g): number of follicular units with > 1 hair before n = 25 (20x, without immersion fluid); (2 h): increased number of follicular units > 1hair after the treatment n = 30 (20x, with immersion fluid); (2i-j): characteristic for this localisation pattern of blood vessels (blue ring), number of thick hair before n = 10, after n = 15 (70x, without immersion fluid).

burning, or a painful scalp are typical for active LPP and most patients report such complaints when inflammation is present [17], whereas symptom reduction suggests clinical improvement. This is in accordance with our observations. On the contrary, subjective symptoms are rarely observed in FFA [18] however in our study subjective symptoms were reported by majority of patients with FFA. Trichoscopic examination demonstrated a decrease of perifollicular hyperkeratosis which was statistically significant (p = 0.009); perifollicular erythema also decreased, but without statistical significance. It cannot be excluded that reduction of itching, pain or burning sensations are the first

Table 2
Comparison of LPPAI index and FFASS before and after treatment, LPPAI (N = 8), FFASS (N = 8).

Index	Before treatment						After treatment						Statistical test	
	Min	Max	Q1	Me	Q3	IR	Min	Max	Q1	Me	Q3	IR	Z	p
LPPAI	1.66	8.25	2.48	4.66	5.71	3.23	0.00	5.25	0.50	1.33	2.37	1.88	2.521	0.012
FFASS	3.80	15.10	7.90	10.85	14.15	6.25	2.40	14.50	6.90	10.25	12.90	6.00	2.380	0.017

LPPAI – Lichen Planopilaris Activity Index; FFASS – Frontal Fibrosing Alopecia Severity Score.

Table 3
The severity of perifollicular hyperkeratosis before and after treatment (N = 16).

Perifollicular hyperkeratosis before treatment	Perifollicular hyperkeratosis after treatment				
	none	mild	moderate	severe	Total
none	1	0	0	0	1
mild	5	1	0	0	6
moderate	1	1	1	1	4
severe	0	5	0	0	5
Total	7	7	1	1	16

Fisher's exact test p = 0.009.

Table 4
The severity of perifollicular erythema before and after treatment (N = 16).

Perifollicular erythema before treatment	Perifollicular erythema after treatment				
	none	mild	moderate	severe	Total
none	0	0	0	0	0
mild	2	0	0	0	2
moderate	4	4	1	0	9
severe	0	3	2	0	5
Total	6	7	3	0	16

Fisher's exact test p = 0.135.

signs of clinical improvement and precede the reduction of trichoscopic markers of inflammation. The anti-inflammatory effect of LED therapy has been demonstrated in many studies; however, the exact mechanism of its action on hair follicles is not completely understood and requires further studies [2,19]. Reduction of inflammation was observed in 8 patients with LPP after 6 months of daily therapy with 246 red LEDs [8]. This is similar to our findings.

Along with reduction of inflammation, we observed the trend of an increasing total hair count and a significantly increased number of thick hairs within the treated area, which led to a cosmetically acceptable improvement for the patients and is in accordance with the study conducted by Fonda-Pascual et al. [8]. The observed slight increase of the total hair count only involved hair follicles that were not affected by the fibrosing process. Some of them exhibited either perifollicular hyperkeratosis or perifollicular erythema before the study and were located around patches of hair loss. We observed the presence of more hairs within some follicular units. We did not observe any hair regrowth within the scar. It cannot be excluded that slight hair regrowth might involve only those hair follicles where the scarring process did not begin and the predominant feature is inflammation. Therefore, sLED therapy due to its anti-inflammatory and immunomodulatory effect may prevent disease progression and contribute to potential hair regrowth. Harries at al. proposed a model of disease progression from a healthy hair follicle to permanent scarring alopecia. The authors suggested that at the beginning of LPP and FFA, disease progression can be stopped and alopecia could be potentially reversible. However, once scarring has begun, alopecia becomes permanent [16]. Therefore prevention of scarring would be a therapeutic goal in patients with LPP and FFA.

Recently it has been demonstrated in *in vitro* studies that red light LED irradiation with high fluencies definied as equal or greater than 160 J/cm^2 may exert anti-fibrotic effect on the skin [20,21]. In our study we did not observed anti- fibrotic effect or reduction of scarring after sLED therapy which could result from lower fluencies used in our study. It cannot be excluded that irradiation of scalp with higher fluencies than usually used may also exert anti- fibrotic effect in scarring alopecia. However it requires further studies.

Moreover, in our study we observed an increased number of thick hairs within the treated area. This could be explained by the effect of sLED therapy on the hair cycle. It has been suggested that LLLT irradiation lengthens the duration of the anagen phase, stimulates anagen reentry in telogen hair, prevents premature catagen and increases rates of proliferation in active anagen hair [4]. Better hair growth might also result from the vasodilatatory effect of nitric oxide (NO), the production of which is stimulated by photobiomodulation [22]. However, the majority of those observations were made in patients with non-scarring alopecia [4,7,22].

It cannot be excluded that the improvement observed in our study also results from different mechanisms. It is thought that the collapse of immune privilege of the bulge region and inflammation-derived damage of epithelial stem cells of the hair follicle leads to scarring and irreversible hair loss. However, it is still unclear what induces the inflammatory reaction or whether it precedes or follows immune privilege collapse. It is suggested that one of the most important pathways in immune privilege collapse is mediated by interferon-γ (INF-γ) and peroxisome proliferator-activated receptor gamma (PPAR-γ) [16]. Significantly lower gene expression levels of PPAR-γ in unaffected and affected LPP were reported compared to healthy controls [23]. Therefore, it has been suggested that PPAR-γ-targeted therapy may represent a new strategy in the treatment of hair loss [23]. de Lima et al. demonstrated in murine models increased PPAR-γ expression after LLLT irradiation [24]. It was also observed that LED irradiation stimulates outer root sheath cell (ORSC) proliferation and migration which might be related to activation of the Wnt5/β-catenin signalling pathway [25]. Interestingly, the same signalling pathway is needed to promote proliferation of bulge stem cells [26]. Considering this, sLED therapy seems a promising therapeutic option for patients. Therapy of scarring alopecia is difficult and severe cases of LPP or FFA might be resistant to classic drugs [8]. All patients in our study received stable treatment, which was not changed for a minimum of 6 months. The majority of patients enrolled to the study did not start the previous therapy in our Department; therefore, we couldn't compare the efficiency of this previous treatment before and after six months of stable therapy. However, this therapy did not control the disease sufficiently, since trichoscopic signs of inflammation were present in all patients and the majority of them reported severe itching, pain or burning of the scalp. None of the patients experienced satisfactory improvement. Therefore, in our opinion, the previous treatment was not sufficient and we decided to add sLED therapy. In our study, we used sLED therapy as an adjuvant therapy. To obtain comparability of the results, all patients received the same protocol of sLED therapy, including the same: dose per session, distance from the scalp and number of sLED irradiations. All patients also continued their previous treatment without any modification. Therefore, the observed improvement might suggest that sLEDs

Table 5
Comparison of subjective symptoms before and after treatment (N = 16).

Symptoms	Before treatment						After treatment						Statistical test	
	Min	Max	Q1	Me	Q3	IR	Min	Max	Q1	Me	Q3	IR	Z	p
Itch	1.0	10.0	4.5	5.5	8.5	4.0	0.0	3.0	0.0	1.0	1.5	1.5	3.516	< 0.001
Burning sensation	0.0	10.0	1.0	3.0	6.5	5.5	0.0	2.0	0.0	0.0	0.5	0.5	3.180	0.001
Pain	0.0	10.0	0.0	1.5	3.5	3.5	0.0	2.0	0.0	0.0	1.0	1.0	2.666	0.008

Me – median, Q1 – lower quartile, Q2 – upper quartile, IR – interquartile range.

improve the clinical outcome itself or modulate and increase the therapeutic effect of the used medication [10]. However, further randomized studies with larger study groups are required to confirm this hypothesis. Due to the heterogeneous and small study group, the correlation between particular medications and sLED irradiation was not investigated here. All subjects tolerated the therapy well and the treatment protocol with weekly irradiation was comfortable for them. Moreover, due to the "soft start" option, power density increased gradually during the first 4 min, which prevented patients from feeling potentially unpleasant heat at the beginning of the treatment and improved tolerability of this procedure. It has been suggested that optimal therapy should not only alleviate the symptoms but also should not add extra impairment associated with the treatment [27]. It has been speculated that sun exposure could be an environmental trigger for both FFA and LPP [28,29]. The majority of epidemiological studies have been performed among patients from Europe, America and Asia; however, racial or geographic differences have not been fully studied [28–31]. In our study, all patients were exposed to similar environmental factors and to eliminate potential aggravation of symptoms by sun exposure, the therapy was not performed during summer.

Our study was limited by its small sample size, the lack of a control group and lack of follow-up. Therefore, further studies are required including a larger study group and a control group.

6. Conclusions

Given the chronic and progressive character of FFA and LPP, there is need for a safe long-term therapy for those patients. Our study demonstrated that sLEDs with a "soft start" are characterized by good tolerability, increase the chance to inhibit progression of the disease and improve the outcome both in FFA and LPP. This noninvasive therapy leads to the reduction of subjective symptoms as well as trichoscopic and clinical improvement. This effective novel light source can be used as an adjuvant therapy in patients with chronic LPP or FFA. However, further studies including a larger study group and a control group are needed to evaluate the long-term effects of the therapy.

Funding

Medical University of Lublin, Poland, Research Project No. DS 167.

References

[1] J.J. Anders, R.J. Lanzafame, P.R. Arany, Low-level light/laser therapy versus photobiomodulation therapy, Photomed. Laser Surg. 33 (2015) 183–184, https://doi.org/10.1089/pho.2015.9848.
[2] M.R. Hamblin, Mechanisms and applications of the anti-inflammatory effects of photobiomodulation, AIMS Biophys. 4 (2017) 337–361, https://doi.org/10.3934/biophy.2017.3.337.
[3] L.F. de Freitas, M.R. Hamblin, Proposed mechanisms of photobiomodulation or low-level light therapy, IEEE J. Sel. Top. Quantum Electron. 22 (2016), https://doi.org/10.1109/JSTQE.2016.2561201 pii: 7000417.
[4] P. Avci, G.K. Gupta, J. Clark, N. Wikonkal, M.R. Hamblin, Low-level laser (light) therapy (LLLT) for treatment of hair loss, Lasers Surg. Med. 46 (2014) 144–151, https://doi.org/10.1002/lsm.22170.
[5] E. Sorbellini, M. Rucco, F. Rinaldi, Photodynamic and photobiological effects of light-emitting diode (LED) therapy in dermatological disease: an update, Lasers Med. Sci. 33 (2018) 1431–1439, https://doi.org/10.1007/s10103-018-2584-8.
[6] J. Bartosińska, K. Wolska-Gawron, A. Gerkowicz, M. Niewiedzioł, M. Michalska-Jakubus, M. Komza, T. Klepaczewski, M. Kwaśny, D. Krasowska, Photodynamic therapy with the use of superluminescent diodes (sLED) in the treatment of actinic keratosis, Photodiagnosis Photodyn. Ther. 22 (2018) 187–190, https://doi.org/10.1016/j.pdpdt.2018.04.010.
[7] S. Mai-Yi Fan, Y.P. Cheng, M.Y. Lee, S.J. Lin, H.Y. Chiu, Efficacy and safety of a low-level light therapy for androgenetic alopecia: a 24-week, randomized, double-blind, self-comparison, sham device-controlled trial, Dermatol. Surg. 44 (2018) 1411–1420, https://doi.org/10.1097/DSS.0000000000001577.
[8] P. Fonda-Pascual, O.M. Moreno-Arrones, D. Saceda-Corralo, A.R. Rodrigues-Barata, C. Pindado-Ortega, P. Boixeda, S. Vaño-Galvan, Effectiveness of low-level laser therapy in lichen planopilaris, J. Am. Acad. Dermatol. 78 (2018) 1020–1023, https://doi.org/10.1016/j.jaad.2017.11.040.
[9] P. Kotowski, M. Kwaśny, A. Gietka, Superluminescent diodes sLED in photodynamic therapy, Elektronika 11 (2016) 29–33, https://doi.org/10.15199/13.2016.11.6.
[10] C. Chiang, D. Sah, B.K. Cho, B.E. Ochoa, V.H. Price, Hydroxychloroquine and lichen planopilaris: efficacy and introduction of Lichen Planopilaris Activity Index scoring system, J. Am. Acad. Dermatol. 62 (2010) 387–392, https://doi.org/10.1016/j.jaad.2009.08.054.
[11] D. Saceda-Corralo, Ó. Moreno-Arrones, P. Fonda-Pascual, C. Pindado-Ortega, D. Buendía-Castaño, A. Alegre-Sánchez, G. Segurado-Miravalles, A.R. Rodrigues-Barata, P. Jaén-Olasolo, S. Vaño-Galván, Development and validation of the frontal fibrosing alopecia severity score, J. Am. Acad. Dermatol. 78 (2018) 522–529, https://doi.org/10.1016/j.jaad.2017.09.034.
[12] D. Barolet, Light-emitting diodes (LEDs) in dermatology, Semin. Cutan. Med. Surg. 27 (December (4)) (2008) 227–238, https://doi.org/10.1016/j.sder.2008.08.003.
[13] M. Kwaśny, Photodynamic therapy in dermatology, Forum Derm. 4 (2018) 138–147, https://doi.org/10.5603/FD.2018.0002.
[14] M. Kwaśny, P. Kotowski, A. Gietka, Light sources for photodynamic therapy of light-emitting diodes with optical fiber output, Elektronika 58 (2017) 50–54, https://doi.org/10.15199/13.2017.11.9.
[15] E. Rácz, C. Gho, P.W. Moorman, V. Noordhoek Hegt, H.A. Neumann, Treatment of frontal fibrosing alopecia and lichen planopilaris: a systematic review, J. Eur. Acad. Dermatol. Venereol. 27 (2013) 1461–1470, https://doi.org/10.1111/jdv.12139.
[16] M.J. Harries, F. Jimenez, A. Izeta, J. Hardman, S.P. Panicker, E. Poblet, R. Paus, Lichen planopilaris and frontal fibrosing alopecia as model epithelial stem cell diseases, Trends Mol. Med. 24 (2018) 435–448, https://doi.org/10.1016/j.molmed.2018.03.007.
[17] A. Lyakhovitsky, B. Amichai, C. Sizopoulou, A. Barzilai, A case series of 46 patients with lichen planopilaris: demographics, clinical evaluation, and treatment experience, J. Dermatolog. Treat. 26 (2015) 275–279, https://doi.org/10.3109/09546634.2014.933165.
[18] A. Lyakhovitsky, A. Barzilai, B. Amichai, Frontal fibrosing alopecia update, World J. Dermatol. 4 (2015) 33–43, https://doi.org/10.5314/wjd.v4.i1.33.
[19] P. Avci, A. Gupta, M. Sadasivam, D. Vecchio, Z. Pam, N. Pam, M.R. Hamblin, Low-level laser (light) therapy (LLLT) in skin: stimulating, healing, restoring, Semin. Cutan. Med. Surg. 32 (2013) 41–52.
[20] J.K. Nguyen, J. Weedon, J. Jakus, E. Heilman, R.R. Isseroff, D.M. Siegel, J.R. Jagdeo, A dose-ranging, parallel group, split-face, single-blind phase II study of light emitting diode-red light (LED-RL) for skin scarring prevention: study protocol for a randomized controlled trial, Trials 20 (2019) 432, https://doi.org/10.1186/s13063-019-3546-6.
[21] H. Lev-Tov, A. Mamalis, N. Brody, D. Siegel, J. Jagdeo, Inhibition of fibroblast proliferation in vitro using red light-emitting diodes, Dermatol. Surg. 39 (2013) 1167–1170, https://doi.org/10.1111/dsu.12212.
[22] M. Zarei, T.C. Wikramanayake, L. Falto-Aizpurua, L.A. Schachner, J.J. Jimenez, Low level laser therapy and hair regrowth: an evidence-based review, Lasers Med. Sci. 31 (2016) 363–371, https://doi.org/10.1007/s10103-015-1818-2.
[23] P. Karnik, Z. Tekeste, T.S. McCormick, A.C. Gilliam, V.H. Price, K.D. Cooper, P. Mirmirani, Hair follicle stem cell-specific PPARgamma deletion causes scarring alopecia, J. Invest. Dermatol. 129 (2009) 1243–1257, https://doi.org/10.1038/jid.2008.369.
[24] F.M. de Lima, R. Albertini, Y. Dantas, A.L. Maia-Filho, L. Santana Cde, H.C. Castro-Faria-Neto, C. França, A.B. Villaverde, F. Aimbire, Low-level laser therapy restores the oxidative stress balance in acute lung injury induced by gut ischemia and reperfusion, Photochem. Photobiol. 89 (2013) 179–188, https://doi.org/10.1111/j.1751-1097.2012.01214.x.
[25] J.E. Kim, Y.J. Woo, K.M. Sohn, K.H. Jeong, H. Kang, Wnt/β-catenin and ERK pathway activation: a possible mechanism of photobiomodulation therapy with light-emitting diodes that regulate the proliferation of human outer root sheath cells, Lasers Surg. Med. 49 (2017) 940–947, https://doi.org/10.1002/lsm.22736.
[26] Y.S. Choi, Y. Zhang, M. Xu, Y. Yang, M. Ito, T. Peng, Z. Cui, A. Nagy, A.K. Hadjantonakis, R.A. Lang, G. Cotsarelis, T. Andl, E.E. Morrisey, S.E. Millar, Distinct functions for Wnt/β-catenin in hair follicle stem cell proliferation and survival and interfollicular epidermal homeostasis, Cell Stem Cell 13 (2013) 720–733, https://doi.org/10.1016/j.stem.2013.10.003.
[27] F.N. Balieva, A.Y. Finlay, J. Kupfer, L.T. Aragones, L. Lien, U. Gieler, F. Poot, G.B.E. Jemec, L. Misery, L. Kemeny, F. Sampogna, H. van Middendorp, J.A. Halvorsen, T. Ternowitz, J.C. Szepietowski, N. Potekaev, S.E. Marron, I.K. Altunay, S.S. Salek, F.J. Dalgard, The role of therapy in impairing quality of life in dermatological patients: a multinational study, Acta Derm. Venereol. 98 (2018) 563–569, https://doi.org/10.2340/00015555-2918.
[28] A. Beheshtiroy, F. Hajmanoochehri, F. Hossienghamar, An epidemiological study of 97 cases of primary cicatricial alopecia in Iran, Dermatol. Rep. 7 (2015) 5960, https://doi.org/10.4081/dr.2015.5960 eCollection 2015 May 21.
[29] L. Photiou, R.L. Nixon, M. Tam, J. Green, L. Yip, An update of the pathogenesis of frontal fibrosing alopecia: what does the current evidence tell us? Australas. J. Dermatol. (2018), https://doi.org/10.1111/ajd.12945.
[30] F. Mardones, J. Shapiro, Lichen planopilaris in a Latin American (Chilean) population: demographics, clinical profile and treatment experience, Clin. Exp. Dermatol. 42 (2017) 755–759, https://doi.org/10.1111/ced.13203.
[31] J. Meinhard, A. Stroux, L. Lünnemann, A. Vogt, U. Blume-Peytavi, Lichen planopilaris: epidemiology and prevalence of subtypes – a retrospective analysis in 104 patients, J. Dermatol. Ges. 12 (2014) 229–235, https://doi.org/10.1111/ddg.12264 229-36.