The Efficacy of Green Light Emitting Diode on Androgenetic Alopecia: A Pilot Study

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Abstract

Light-emitting diodes (LEDs), a form of low-level laser therapy (LLLT), represent noninvasive and affordable modalities for various dermatological conditions, including androgenetic alopecia (AGA). While most research favors red LED therapy for hair regeneration, a study on mice highlighted the superior efficacy of green LED light. Nevertheless, no human trials have explored the potential of green LED therapy for hair growth. Thus, the aim of this research was to evaluate the effects of 530 nm green LED light on hair growth in frontal recession areas. This pilot study involved eight participants aged 30 to 60 years with AGA who underwent weekly sessions of green LED helmet treatment for 12 weeks. Primary outcomes included dermatologist and participant satisfaction, assessed through a 7-point scale at baseline, week 4, week 8, and week 12. Dermatologist satisfaction scores demonstrated significant improvement starting from the 12-week follow-up compared to baseline. Notably, a majority of subjects (50%) reported a slight increase in hair thickness. The participants' satisfaction scores exhibited statistically significant improvement from the 4th week follow-up and remained significant at the 12th week follow-up, with 37.5% reporting a slight increase and another 37.5% reporting a moderate increase in hair thickness. According to the findings of the study, green LED at 530 nm is safe and has the potential to be used as an effective adjunctive modality for hair regrowth. The study's limitations, namely a small sample size and short duration, indicate that future research should be conducted.

Keywords: *Light-Emitting Diodes, Green Light, Androgenetic Alopecia, Hair Growth*

1. Introduction

Androgenetic alopecia (AGA), also referred to as male and female pattern hair loss, stands as the most prevalent type of alopecia. It affects up to 80% of men and 50% of women throughout their lifetime (Piraccini, & Alessandrini, 2014). AGA is influenced by a genetic predisposition and sensitivity of hair follicles to androgens. This results in a gradual reduction of the anagen phase and an extended telogen phase, leading to the gradual transformation of terminal scalp hair into vellus hair, or the process of miniaturization (Bajoria et al., 2023). AGA has impacts on appearance and can have profound psychological effects, which can ultimately contribute to lower self-esteem and affect the quality of life (Al Najjar et al., 2023; Dhami, 2021). The standard treatment for AGA involves oral finasteride and topical minoxidil. However, their effectiveness is limited and may come with undesirable side effects (Rogers, & Avram, 2008).

Another modality apart from medication that has been approved by the US FDA for treating AGA is low-level light therapy (LLLT) (Nestor et al., 2021). The mechanism of LLLT is not completely known, however it is believed that the absorption of light by cytochrome c oxidase (CCO) within mitochondria triggers photodissociation of inhibitory nitric oxide (NO), which leads to increased production of ATP, regulation of reactive oxygen species, and activation of transcription factors (Nestor et al., 2021). The wavelengths commonly utilized in LLLT devices for AGA treatment typically range from around 630 nanometers (nm) to 670 nm, which involves the use of red and near-infrared light-emitting diodes (LEDs) (Nestor et al., 2021). Red LED light was discovered to penetrate 2–3 millimeters, which can possibly penetrate the scalp and reach the hair follicles. Studies suggest that red light therapy increases the production of cellular energy (ATP) and reduces inflammation, both of which are crucial factors in combating hair loss (Pillai, & Mysore, 2021). In prior randomized controlled trials by Lanzafame et al., it was reported that for the LLLT-treated group using the device, which consisted of 21, 5 mW lasers with a wavelength of 655 ± 5 nm, and 30 LEDs with a wavelength of 655 ± 20 nm, the results showed an increase in hair count, with a 35% improvement observed in male patients and a 37% improvement in female patients compared to sham-treated controls (Lanzafame et al., 2013; Lanzafame et al., 2014). However, recently in 2022, Kittigul et al. reported that the results from the experimental study in mice showed that the novel green light with the wavelength of 513 nm had the most stimulatory effect on hair growth, which was significantly superior to other modalities, including red LED and 5% topical minoxidil (Kittigul et al., 2023). Thus far, green light has been studied in many aspects of dermatology including wound healing, port-wine stains, and solar keratoses (Fritsch et al., 1997; Li-Qiang et al., 2018). However, despite findings in animal studies demonstrating the positive benefits on hair growth in mice, there have been no studies conducted to assess the effectiveness and safety of green LED therapy in promoting hair regrowth in humans. Therefore, it is essential to conduct human studies to further explore and validate these potential effects.

2. Objectives

The aim of this study was to evaluate the efficacy of green LED in stimulating hair growth in AGA patients by comparing the clinical pre- and post-treatment conditions.

3. Materials and Methods

3.1 Study design

This pilot study involved a total of eight participants, ranging in age from 30 to 60 years old. Participants with AGA Hamilton-Norwood Stages III to IV (including Type III vertex) and female pattern hair loss Ludwig types I-II were included in the study. Results suggest that patients with male AGA (Hamilton–Norwood III and IV) and female AGA (Ludwig I and II) respond best, since effectiveness depends on a minimum of hair for effective photobiostimulation and a maximum of hair for the laser beam to reach the scalp without absorption or interference from existing hairs (Pillai, & Mysore, 2021). Subjects were required to maintain the normal hair length, color, and style during the study. Exclusion criteria were subjects who were undergoing treatment for the disease before this study period, including treatment with topical medication within 6 months, treatment with systemic medication (finasteride within 12 months, dutasteride within 18 months), using shampoo for hair growth stimulation, taking hair supplements within 3 months and patients with a history of hair transplantation or restoration surgery, which may introduce variability in the treatment response, making it difficult to isolate the effects of green LED therapy. The research received approval from the Human Research Ethics Committee of Thammasat University (Medicine) under reference number MTU-EC-OO-6-241/65. Prior to their participation in the study, all of the subjects provided informed consent.

3.2 Research device

The research used a green LED source with a wavelength of 530 nm, which was newly invented (Figure 1). Our LED helmet delivers irradiance levels of 50 mW/cm². These levels were selected to deliver an effective dose of light to the scalp while ensuring patient safety and comfort. The energy that is used to stimulate hair growth when calculated from the light source is 40 J/cm2. The light source is placed 10 cm above the scalp, and the energy that accumulates at the depth of 1 mm from the scalp surface is 5.27 J/cm2. The energy of this device was determined based on the energy of the LED phototherapy devices which are FDA approved in the general market.

3.3 Study protocol

All participant that matched the requirements received one treatment session per week for a duration of 12 weeks, comprising a total of 12 treatment sessions. The frontal recession was irradiated with the green LED. Each subject underwent 20 minutes of green LED light irradiation per treatment session, one session per week at Benchakitti Park Hospital. The clinical evaluation was obtained at baseline, and 4, 8, and 12-week follow-ups. Digital photographs were obtained using a Sony DSC-RX100M3 digital camera with 1-fold magnification with the same settings at baseline and the follow-ups.

3.4 Outcomes assessment

Clinical improvement assessments of hair thickness by one dermatologist and the participants' satisfaction were performed using 7-point satisfaction scores. The values of each of the scores were: Significantly decreased hair thickness (-3), Moderately decreased hair thickness (-2), Slightly decreased hair thickness (-1), No hair thickness change (0), Slightly increased hair thickness (1), Moderately increased hair thickness (+2), and Significantly increased hair thickness (+3).

3.5 Statistical Analysis

The authors hypothesized that the treatment with green LED at 530 nm wavelength on hair growth would improve between before and after treatment. Descriptive analysis was used for the demographic data. Clinical data analyses that included a comparison of the results at different study times versus baseline were conducted. The results are in ordinal data (ranking), therefore the Wilcoxon signed-rank test, which is a non-parametric statistical test, was carried out in order to compare the changes in parameters at each visit compared to baseline. Data were analyzed using SPSS software, and P-values of < 0.05 were considered statistically significant.

Figure 1 Green LED helmet

4. Results and Discussion

4.1 Results

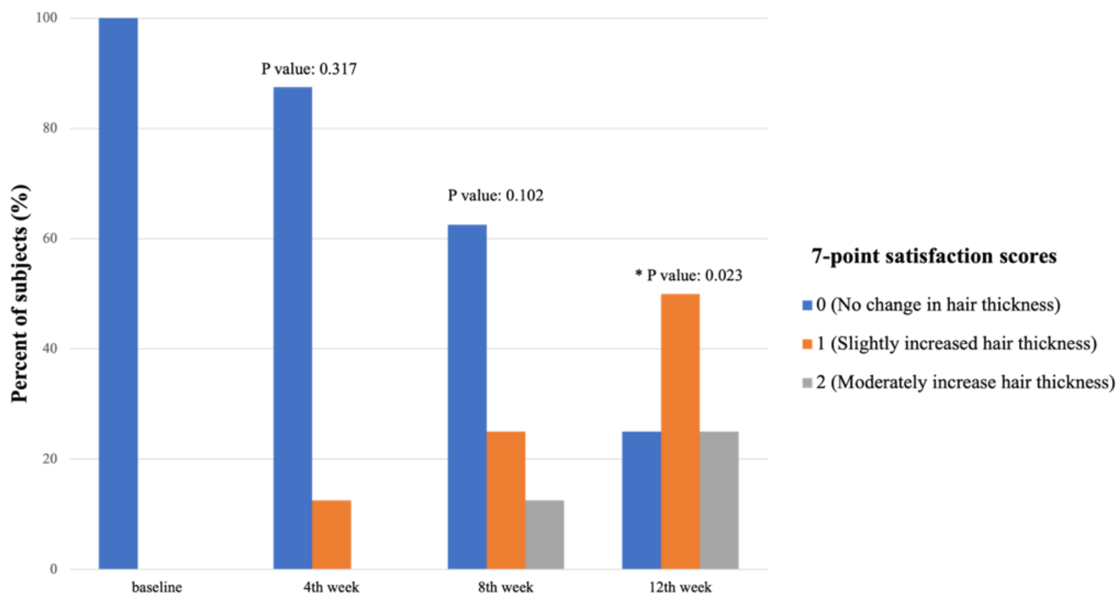
The study enrolled eight participants, consisting of five males and three females, who satisfied the inclusion criteria. The majority of the male subjects (80%) had Androgenetic Alopecia (AGA) grade 3, while the majority of female subjects (66.7%) had Female Pattern Hair Loss (FPHL) grade 2. All eight subjects successfully completed the entire treatment. The demographic data of the participants are summarized in Table 1.

The evaluation of the dermatologist's satisfaction score for hair thickness was recorded at 4-, 8-, and 12-week follow-ups, as presented in Figure 2. The dermatologist's satisfaction score showed that at the 4-week and 8-week follow-ups, the majority of the subjects had no change in hair thickness. However, at the 12-week follow-up, most patients had an increase in hair thickness. Specifically, 50% of the patients scored slightly increased hair thickness, and 25% scored moderately increased hair thickness. There were still 25% of the patients who showed no change in hair thickness at the 12-week follow-up. Statistically significant differences were observed in the scores at the 12-week follow-up compared to baseline, with a significance level of $p = 0.023$, as determined by the Wilcoxon signed-rank test.

The evaluation of the subjects' satisfaction scores for hair thickness was documented at the 4-, 8-, and 12-week follow-ups, as shown in Figure 3. The subjects' satisfaction scores indicated that most experienced a slight increase in hair thickness at both the 4- and 8-week follow-ups. By the 12-week assessment, the majority (75%) reported an improvement in hair thickness, with 37.5% scoring a slight increase and another 37.5% scoring a moderate increase in thickness. The scores exhibited statistical significance at $p < 0.05$ during the 4-week follow-up in contrast with baseline. We took note of possible side effects including headaches, skin pain, burning sensations, pruritus, erythema, and acne (Nestor et al., 2021). However, throughout the treatment period, all subjects (100%) experienced no reduction in hair thickness and no adverse events from the treatment.

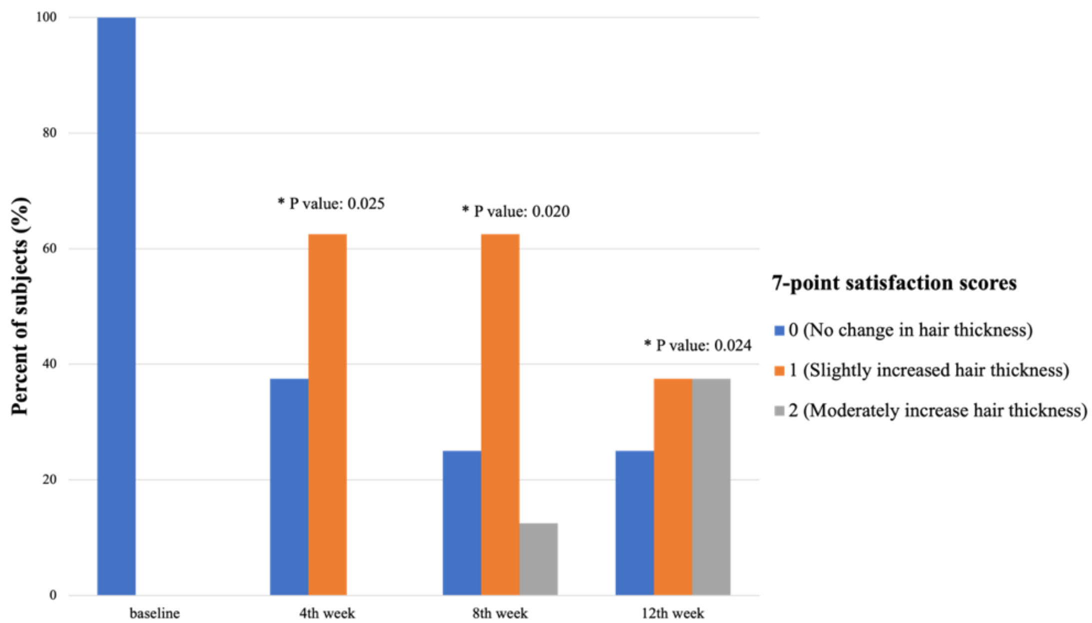
Table 1 Demographic data of subjects enrolled in the study (n = 8)

Characteristics				**Value (%) n = 8**
Age (years), mean ± SD				49.38 ± 9.15
Sex	female	FPHL grade	1	1 (33.3%)
			2	2 (66.7%)
	male	AGA grade	3	4 (80%)
			6	1 (20%)



*Statistically significant at P-value < 0.05 compared with baseline

Figure 2 Dermatologist's satisfaction scores



*Statistically significant at P-value < 0.05 compared with baseline

Figure 3 Subjects' satisfaction score

Figure 4 Changes in hair thickness on frontal recession using digital photography from baseline, 4-, 8- and 12-week follow-ups

4.2 Discussion

LEDs, as a form of LLLT, are now used to treat dermatologic conditions such as photoaging, acne, wound healing, and hair loss (Avci et al., 2013). LEDs provide a non-invasive and downtime-free procedure for hair loss management which operates through photobiomodulation, stimulating mitochondria situated in the stem cells located within the hair bulge. The light targets cytochrome c oxidase (CCO), inducing mitochondrial respiration, leading to the release of ROS and ATP that stimulate cellular activities and foster hair growth (Hamblin, 2019). Red light (630 nm to 670 nm) is commonly used in LED devices for AGA, while a study in mice suggests positive effects on hair regrowth with green light (513 nm), indicating its potential as a novel AGA treatment (Kittigul et al., 2023).

Green light has been studied and reported to benefit in the treatment of various dermatological conditions such as chronic lichen sclerosus, port wine stains (PWS) and basal cell carcinoma (BCC) (JalalKamali et al., 2018; Li-Qiang et al., 2018; Osiecka et al., 2017). A research study emphasized the superior results of green LEDs in comparison to red and blue LEDs in reducing wound size in mice. This was achieved by enhancing the mediators involved in migration and proliferation, such as leptin, IL-8 and VEGF, and also inducing fibroblast proliferation (Fushimi et al., 2012). However, there is a lack of research investigating its potential effects on hair regeneration. Green LED light typically penetrates the skin to a depth of 0.5 to 2 mm beneath the surface, potentially exerting more localized effects on the superficial layers of the scalp, including the epidermis and upper dermis (Kittigul et al., 2023), primarily affecting the area of the hair follicle bulge (Jimenez et al., 2011). Moreover. green LED light can stimulate cellular activity and promote wound healing (Kittigul et al., 2023). In this context, green light has the potential, similar to red light, to penetrate the scalp and influence the mitochondria, affecting energy production and stimulating cellular activity. This potential influence could promote hair regrowth.

In 2007, a study investigated the effects of using a portable red to near-infrared LED light sources (655 and 780 nm) in patients with AGA for 14 weeks. The study measured patient satisfaction scores, with 83% of the patients reporting satisfaction with the treatment (Kim, 2007). In our study, all participants received the treatment with green LEDs for a cumulative total of 12 sessions. Dermatologist satisfaction assessment scores showed a significant increase in hair density at the 12-week follow-up compared to baseline, with 75% of the subjects achieving an improvement in frontal hair density. Figure 4 illustrates clinical images of the evolution of a subject's frontal recession from the initial assessment at baseline to the follow-up evaluations at week 4, week 8, and week 12, indicating noticeable hair growth and density improvement from week 4 to week 12 compared to baseline. In the subjects' self-assessments, 62.5% of the subjects reported a slight increase in frontal hair density in the 4th week, and after continuing the treatment to the 8th and 12th weeks, 75% of the subjects reported an increase in frontal hair density and were satisfied with the results at the final stage of the treatment. The outcomes from this study indicate that green LED at a wavelength of 530 nm is effective in hair regeneration, and the level of satisfaction was almost comparable to the generally used red LED as mentioned above.

Nevertheless, this study was limited by the small sample size and the short duration period. Moreover, there was no objective assessment of hair thickness; therefore, a long-term study of its efficacy and more objective assessments, such as hair count with dermoscopy, hair tensile strength, or standardized global photography should be conducted. Additionally, since this research is not a double-blinded study, confirmation bias from the evaluators is possible. Furthermore, to establish green LED as a viable alternative treatment to red LED, future research should focus on comparing the efficacy of green LED with that of red LED.

5. Conclusion

After undergoing treatment with green LED irradiation, subjects exhibited clinical improvement in hair growth. This suggests that green LED light at 530 nm is safe and can be considered as an additional method for promoting hair regeneration in androgenetic alopecia (AGA).

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