A SYSTEMATIC REVIEW OF LASER-BASED TREATMENTS FOR HAIR FALL

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Objective: Hair loss, or alopecia, is a common condition affecting both men and women. Various treatment options exist, including medications, hair replacement, and more recently, laser therapies. This systematic review aims to compare the efficacy of different laser treatments for hair loss, including low-level laser therapy (LLLT), excimer laser, erbium glass laser, erbium YAG laser, and CO2 laser.

Methodology: A comprehensive literature search was conducted using Google Scholar to identify relevant studies on laser treatments for hair loss. Inclusion criteria encompassed English-language original research articles and clinical trials reporting quantitative or qualitative outcomes of laser treatment for hair loss.. Twenty nine studies meeting the inclusion criteria were synthesized narratively and presented in a tabular format.

Results: The review found that various laser treatments showed promising results in promoting hair regrowth. LLLT demonstrated consistent improvements in hair count and density across multiple studies, with increases ranging from 35% to 120% depending on the treatment area and patient sex. Excimer lasers showed hair regrowth in 41.5% to 60% of treated patches. Erbium glass, erbium YAG, and CO2 lasers also exhibited positive outcomes, improving hair density, shaft thickness, and inducing the anagen phase of hair growth.

Conclusion: This systematic review suggests that laser treatments, particularly LLLT and excimer lasers, show efficacy in treating hair loss. However, the small sample sizes in many studies indicate a need for larger clinical trials to further validate these findings. Future research should focus on optimizing treatment parameters, comparing the efficacy of different laser types and potentially exploring visible light therapy to provide more targeted and cost-effective treatment options for patients suffering from hair loss.

Keywords: Laser, Hairfall, Alternative Treatment, Color Therapy.

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INTRODUCTION

Hair is composed of a durable protein called keratin, and the base of each hair follicle is formed by the hair bulb [1]. Each hair strand resides in a small cavity or follicle. The hair shaft consists of four layers: the cuticula (the outermost layer), the cortex (which protects the interior of the hair shaft from damage), the medulla, and the macrofibril (the innermost layer) [2].

Hair loss, or baldness, refers to the loss of hair from the scalp or body [3]. More severe forms of hair loss are referred to as alopecia areata (AA). Several factors contribute to hair loss:

1. A family history of baldness can predispose a person to hair loss.
2. Certain sex hormones may trigger hereditary hair loss [4].
3. Dihydrotestosterone (DHT), a byproduct of testosterone, is a specific hormone linked to hair loss.
4. Hair loss can also be triggered by major illnesses, surgeries, or traumatic events.
5. Hormonal changes are another cause of hair loss.
6. Medical conditions such as thyroid disease and alopecia areata can result in hair loss.
7. The use of styling products and tools, like blow dryers, heated combs, and hair straighteners, can also lead to hair loss.

There are several treatment options for hair loss, including medications, hair replacement techniques, platelet-rich plasma (PRP) therapy, and laser treatments. Rogaine and Propecia are the only medications approved to treat pattern baldness or hair loss of hereditary origin.

Permanent hair loss can also be addressed through hair replacement techniques like "hair transplantation." PRP involves an autologous solution of plasma with a platelet concentration 4-7 times higher than the baseline level [5].

Laser treatments: Alopecia areata (AA) is an autoimmune disorder characterized by round or oval patches of non-scarring hair loss [6, 7]. Several laser types have been proposed for treating localized AA [8]. These include low-level laser therapy (LLLT), the 308-nm excimer laser, and fractional lasers. The term “laser” stands for “Light Amplification by the Stimulated Emission of Radiation.” A laser is a device that produces light through optical amplification, which involves the stimulated emission of electromagnetic radiation [9]. This process occurs when a photon prompts an excited atom to drop to a lower energy state, releasing a second photon that matches the stimulating photon's wavelength and phase [10]. Laser light is distinct from ordinary light because it is monochromatic (consisting of a single wavelength and phase), directional (emitting radiation in a specific direction), and coherent (allowing for regular interference among multiple beams).

Rather than being a simple amplifier, a laser functions as an oscillator due to its positive feedback mechanism. It only operates when the stimulated emission of excited atoms surpasses spontaneous emission [9].

MATERIAL AND METHODS

This systematic review aims to assess the effectiveness of laser treatments for hair loss. The primary search was performed using Google Scholar as the main database. The search strategy included various combinations of keywords such as "laser," "hair loss," "alopecia," "hair regrowth," and "hair fall treatment."

Inclusion criteria were:

1. Studies published in English
2. Original research articles and clinical trials
3. Studies focusing on the use of lasers for treating hair loss
4. Studies reporting quantitative or qualitative outcomes of laser treatment for hair loss.

Exclusion criteria were:

1. Review articles, meta-analyses, and systematic reviews
2. Studies not directly related to laser treatment for hair loss
3. Case reports and studies with insufficient data

The search was not limited by publication date to ensure a comprehensive review of the literature. The titles and abstracts of the retrieved articles were screened for relevance, and the full texts of studies that appeared potentially eligible were reviewed to confirm their inclusion

Data extraction was carried out using a standardized form, which captured details from each study, including the author(s), year of publication, type of laser used, number of patients, and the main results or outcomes. Factors such as sample size, study design, and clarity of reported outcomes were considered when interpreting the results.

A total of 20 studies that met the inclusion criteria were identified and included in the final review. These studies encompassed various types of lasers, including low-level laser therapy (LLT), excimer laser, Er:glass laser, Er:YAG laser, and CO2 laser. The findings were summarized narratively and presented in a tabular format to offer a comprehensive overview of the existing evidence on laser treatments for hair loss.

This methodology allowed for a systematic approach to gathering and presenting the available evidence on laser treatments for hair loss, providing a foundation for further analysis and discussion of the efficacy of these treatments.

Types of lasers for the treatment of hair-fall: Various lasers have been investigated for treating alopecia areata, each utilizing different mechanisms to promote hair regrowth. One such laser is the excimer laser, a type of ultraviolet laser frequently used in microelectronics and semiconductor manufacturing. This laser is often more precisely termed an "exciplex" laser because many excimer lasers involve noble gas halides [11]. The excimer laser, developed by Nikolai Basov in 1970, uses a xenon dimer (Xe_2) stimulated by an electron beam to emit at a wavelength of 172 nm [12]. Typically, it consists of a noble gas (argon, krypton, or xenon) mixed with a reactive gas (fluorine or chlorine) under high pressure and subjected to electrical stimulation [13, 14].

Another method is Low-Level Laser Therapy (LLLT), which utilizes red light within the 600–1000 nm wavelength range or near-infrared light [15]. The concept of LLLT for hair loss was first introduced in 1967, with the underlying mechanisms proposed in 1989. The therapy works through the absorption of visible and near-infrared light by the components of the cellular respiratory chain, particularly affecting mitochondria [16].

A significant approach to hair regrowth involves stimulating hair growth during wound healing, a principle that underpins certain laser treatments for hair loss [17]. For example, fractional non-ablative photothermolysis uses a 1550 nm Erbium glass laser to create "microthermal treatment zones (MTZs)" that penetrate the reticular dermis without damaging surrounding tissue or the stratum corneum [18]. This process, believed to trigger hair growth, is thought to work by inducing T-cell apoptosis and directly promoting hair growth [19].

The Fractional Erbium YAG Laser (ErYAG) is another option, which is a solid-state laser where the

YAG crystal (Yttrium Aluminium Garnet) is infused with an active lasing medium. ErYAG lasers emit infrared light at 2940 nm, a wavelength that is highly absorbed by water, facilitating its use in various dermatological treatments.

Additionally, the Fractional CO_2 Laser, an ablative laser therapy, has been found to be more effective in combination with hair growth factors than using growth factors alone [20]. This laser, commonly explored for alopecia treatment, operates at a wavelength of 10,600 nm and is particularly effective for skin ablation due to its strong affinity for water. While the CO_2 laser alone has shown promise in promoting hair regrowth, its effectiveness is enhanced when used alongside hair growth factors.

RESULTS

Table 1 summarizes findings from various studies examining the efficacy of lasers in treating hairfall, utilizing different laser types across multiple patient cohorts. The studies investigated lasers such as Low-Level Laser Therapy (LLLT), Excimer laser, Erbium (Er): glass laser, and CO_2 laser across diverse patient populations.

Low-Level Laser Therapy (LLLT) and other laser treatments have consistently demonstrated positive outcomes in promoting hair regrowth. A study by Yamazaki et al. [21] found that 46.7% of irradiated areas exhibited earlier hair regrowth compared to non-irradiated areas, with results appearing 1.6 months sooner. Satino et al. [22] reported a significant increase in hair count in both men and women, with men experiencing a 120% increase in the vertex region and 74% in the temporal region, while women showed a 65% increase in the vertex area and 55% in the temporal area. Additional support comes from Waiz et al. [23], who reported hair regrowth in 94% of treated patches, and Kim et al. [24], who observed an 83% increase in hair density.

Several more studies have confirmed these results, such as Kim et al. [25] and Lanzafame et al. [26], who found a 35% increase in hair growth, and Abdelhalim et al. [27], who reported significant increases in hair count. LLLT continues to show promise in other investigations, including a study by Leavitt et al. [40] on the HairMax LaserComb, which demonstrated a significant increase in hair density in 110 male participants. Jimenez et al. [41] further supported this by showing substantial hair growth improvements in both males and females in their 2014 study.

Excimer lasers also play a crucial role in hair regrowth. Al-Mutairi [28] reported 41.5% regrowth in hair patches, with a follow-up study showing improvement up to 60% [29]. Byun et al. [30] confirmed the effectiveness of localized treatment with a single-patch method, indicating the benefits of targeted laser regrowth.

Erbium (Er):glass and CO_2 lasers have also yielded positive outcomes. Lee et al. [31] reported improvements in hair density and shaft thickness, while Wu et al. [32] and Eckert et al. [33] observed significant regrowth with the correct laser settings. Kim et al. [42] found incremental regrowth in male pattern baldness using a 1,550-nm fractional erbium-glass laser, while Meephansan et al. [47] noted a significant increase in hair count and shaft diameter in their study.

In the case of fractionated lasers, Cho et al. [43] demonstrated enhanced hair density and thickness with the 1927-nm fractionated Thulium laser. Day et al. [44] similarly showed improvements in hair growth and a reduction in androgenetic alopecia (AGA) grade using the Er:YAG laser.

CO_2 lasers, especially when combined with other treatments, have proven effective. Bae et al. [36] and Hanthavichai et al. [45] found improved hair growth and density using a combination of CO_2 fractional lasers and platelet-rich plasma (PRP). Huang et al. [46] reported a 93% improvement in the combined group and 67% in the growth factor group in their 2017 study. Salah et al. [48] also noted significant hair thickness improvement when combining CO_2 lasers with Minoxidil.

Other notable studies include Avram et al. [49], who observed an increase in shaft diameter and total terminal hair count using LLLT, and Munck et al. [50], who reported significant or moderate improvement in hair growth for most participants.

Table 1: A detailed review on the studies using lasers in the treatment of hair-fall.

Author	Laser	Year of study	No. of patients	Results
Yamazaki et al. [21]	LLT	2003	15 patients	Hair regrowth was observed 1.6 months earlier in 46.7% of the irradiated areas compared to the non-irradiated areas.
Satino et al. [22]	LLT	2003	35 patients	Both sexes showed significant improvements in hair count across all areas. In the temporal area, hair count increased by 55% in women and 74% in men. In the vertex area, the increase was 65% for women and 120% for men.

Waiz et al. [23]	LLT	2006	16 patients	Hair regrowth occurred in 94% of the patches.
Kim et al. [24]	LLT	2007	24 patients	83% increase in hair density on both the vertex
Al-Mutairi [28]	Excimer laser	2007	8 patients	Regrowth of hair in 41.5% of patches
Al-Mutairi [29]	Excimer laser	2009	9 patients	Hair regrowth occurred in 60% of the patches.
Lee et al. [21]	Er: glass laser	2011	28 females	Improved hair density and hair shaft thickness
Kim et al. [25]	LLT	2013	40 patients	35% increase in hair growth
Lanzafame et al. [26]	LLT	2013	44 patients	35% increase in hair growth
Abdelhalim et al. [27]	LLT	2014	23 patients	The treated patches showed a significant increase in hair counts compared to the control patches.
Byun et al. [30]	Excimer laser	2015	10 males	A single patch was split into treated and untreated sections.
Wu et al. [32]	Er: glass laser	2015		Improved hair growth at appropriate laser settings.
Ke et al. [35]	Er: YAG laser	2015	88 patients	Improved induction of anagen phase in laser treated group, further increase in hair growth.
Bae et al. [15]	CO2 laser (10600 nm)	2015	18 patients	Improved hair growth at most laser settings.
Issa et al. [38]	CO2 laser (10600 nm)	2016	5 patients (1 male, 4 female)	All patients showed improvement.
Eckert et al. [33]	Er: glass laser	2016	5 patients	Almost full regrowth in all patients
Huang et al. [37]	CO2 laser (10600 nm)	2017	28 males	Improved hair density and hair shaft diameter.
Bertin et al. [34]	Er: glass laser	2018	4 (3 males, 1 female)	All patients reported visual improvement.
Leavitt et al. [40]	LLLT (HairMax LaserComb)	2009	110 males	Significant increase in hair density compared to the control group.
Jimenez et al. [41]	LLLT	2014	128 males & 141 females	Significant improvement in hair growth compared to the control group.
Kim et al. [42]	1,550-nm fractional erbium-glass laser	2012	20 males	Incremental hair regrowth in male pattern baldness.
Cho et al. [43]	1927-nm Fractionated Thulium Laser	2016	10 patients	Enhanced hair density and thickness using fractionated laser
Day et al. [44]	Er:YAG Laser	2021	7 male & 9 females	Effective for improving hair growth and decrease in AGA grade.
Hanthavichai et al. [45]	CO_2 Fractional Laser + PRP	2022	7 patients	Combination treatment led to improved hair growth and density.
Huang et al. [46]	CO_2 Fractional Laser	2017	28 males	93% improvement in the combined group and 67% in the growth factor group.
Meephansan et al. [47]	Erbium-Glass Laser	2018	23 patients	Significant increase in hair count and shaft diameter.
Salah et al. [48]	CO_2 Laser + Minoxidil	2020	45 males	The treatment led to a significant increase of hair thickness in the combined group.
Avram et al. [49]	LLLT	2009	7 patients	Increase in the shaft diameter and the total number of terminal hairs
Munck et al. [50]	LLLT	2014	11 male & 21 female	Significant improvement for 8 patients and moderate improvement for 20.

Conclusion: Recent years have seen an increase in research on laser treatments for hair loss and alopecia areata (AA Hair loss is believed to be a T-cell disorder (T-cells are lymphocytes in the thymus gland). The excimer laser is able to induce T-cell apoptosis for hair regrowth. For this reason, the excimer laser has been studied the most. Other lasers explored for treating hair loss and alopecia areata include the erbium glass laser, erbium YAG laser, CO_2 laser, and low-level laser therapy (LLLT), each working through different mechanisms. The studies reviewed involved small sample sizes, indicating a need for larger clinical trials. Further research could expand the availability of these laser treatments for patients in the future.

Another potential area of research is the usage of visible light spectrum, particularly colour therapy [51, 52], for the treatment of hairfall. Unlike laser therapies, which often require specialized equipment and can be more costly, visible light treatments could be more accessible and affordable, as they do not rely on high-intensity laser devices. Further research is necessary to explore the optimal wavelengths, treatment duration, and intensity for effective results in hair regrowth. Additionally, the safety and efficacy of combining visible light therapy with existing hair growth treatments such as Minoxidil or PRP could provide synergistic effects, making it an appealing option for broader, more affordable hair restoration solutions in the future.

Based on the reviewed articles, it can be concluded that:

- The excimer laser is the most studied for the treatment of hair loss and has better efficacy, as it induces T-cell apoptosis.
- LLLT has better efficacy and provides safe treatment as it uses red light from the visible spectrum.
- The erbium glass laser has better results than the erbium YAG and CO2 lasers in treatment. The CO2 laser combined with hair growth factors has better results.

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