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Efficacy of lasers and light sources in long-term hair reduction: a systematic review

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ABSTRACT

Laser and light-based devices provide scope for long-term "hair-removal" however, there is limited evidence supporting their long-term efficacy. This study aimed to assess the long-term efficacy of laser and light-based "hair-removal" devices, taking into account variations in body site-specific variations in hair growthcycles. A systematic review of randomized controlled trials (RCTs) with follow-up periods greater than or equal to the length of one complete hair growth cycle in the body site targeted was conducted. Only five eligible RCTs were identified as suitable for inclusion, and these comprised a total of 223 patients. The average long-term hair reduction reported for neodymium:yttrium-aluminum-garnet (Nd:YAG) laser ranged from 30 to 73.61%, Alexandrite laser ranged from 35 to 84.25%, and Diode laser ranged from 32.5 to 69.2%. In all three devices, the greatest long-term reduction was observed from trials targeting leg hair (1-year growth cycle) and lowest from targeting facial hair (6-month growth cycle). Intense pulsed light (IPL) produced average long-term hair reduction of 52.7–27%; smallest reduction was observed from targeting the face area and greatest from targeting the axillary area (7-month growth cycle). In conclusion, greater long-term hair reduction was observed on body sites with longer hair growth cycles. Future trials should take into account the variation of hair growth cycles across body sites to provide accurate long-term data on treatment outcomes.

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Laser; IPL; Evidence-based research; hair removal; growth cycles

Introduction

Over 40% of women in the general population have some degree of unwanted hair growth (1). Up to 10% of these women are of reproductive age and suffer from hirsutism, which is defined as the presence of thick terminal hairs in androgen-dependent areas of the body due to excess circulating androgens – most commonly as a result of polycystic ovarian syndrome (PCOS) (2,3). Notably, most individuals affected by unwanted or "excessive" hair have no underlying medical conditions; however, their symptoms still cause significant distress. Several trials have investigated the impact of unwanted hair on an individual's quality of life and psychological well-being and have found an increased risk of suffering from emotional distress, depression, and social isolation (4–9). Therefore, the effective long-term removal of unwanted hair within these patients is important to prevent and reduce the associated negative psychological sequelae. The advent of laser and light-based hair removal systems and their increasing popularity for "long-term" hair removal offers a potentially effective therapeutic opportunity (10–15). However, with a lack of robust evidence concerning their safety and efficacy profiles, there is an urgent need for more comprehensive studies.

Functionally, laser hair-removal systems utilize the theory of selective photothermolysis, which involves targeting an area capable of absorbing light at a specific wavelength (chromophore) (2,11,12,16). The commonest chromophore targeted is melanin, which is a pigment concentrated within the hair follicle and not found in the dermis and thus enables targeted destruction of the follicle without nearby structure damage (10,12,16,17). Understanding laser parameters is important in targeting hair removal specifically to individual patients. Laser hair-removal devices range from shorter wavelengths, e.g. 694 nm Ruby laser, which generally produces more superficial penetration due to increased scattering absorption pattern, which causes increased competition with other chromophores (particularly hemoglobin) to mid-spectrum 755 nm Alexandrite and 800–810 nm Diode laser to the 1064 nm neodymium:yttrium-aluminum-garnet (Nd:YAG) laser, which displays such low melanin absorption that very high fluences or short pulse durations must be present for effective hair shaft heating (2,12,17,18). Intense pulsed light (IPL) is another device used for hair reduction and can limit wavelengths to a specific portion of the spectrum (2,12,17), varying from 590–1,200 nm depending on what filter is selected (17,19).

Hair follicles repeatedly undergo three phases in their growth cycle, namely, anagen (growth), catagen (regression), and telogen (rest) (2,20). Hair at different body sites grows at different rates with differing anagen:telogen ratios (20,21). The duration of the anagen phase varies significantly depending on various factors, e.g. age, season, gender, body site, and hormones (2). The catagen phase is usually around 3 weeks long, while telogen is usually around 3 months (2). During telogen, the bulb of the hair is unpigmented because of cessation of melanogenesis during catagen (18). During early anagen, the process of melanogenesis in the bulb resumes so the bulb becomes located more superficially,

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closer to the bulge, and so the bulge cells are more susceptible to injury (18). With the progression of anagen, the bulb and papillae move down and beyond the dermis (18). As a consequence of this, the late anagen hairs may also be relatively resistant to damage by laser pulses (18). Therefore, follicles should theoretically be most susceptible to laser damage during the early anagen stage. Hair growth cycles have been observed to be as follows: face, 6 months; axilla, 7 months; forearm, 8 months; pelvic area, 7 months; buttock, 1 year; calf/ thigh, 1 year (22).

Understanding the effects of different laser parameters and how individual characteristics, e.g. growth site targeted and hair-cycle phase effect laser/IPL efficacy is key in maximizing therapeutic effects in those who experience psychological stress due to unwanted hair; however, limited evidence is currently available. Few reviews have compared efficacy of lasers and light sources (23–26). To the best of our knowledge, this is the first systematic review that has evaluated data on long-term laser hair-reduction outcomes while also taking into account differing hair growth cycles of treatment sites when comparing "long-term" efficacy of hair reduction.

Materials and methods

This systematic review was prepared in concordance with the recommendations of the Preferred Reporting Items of Systematic Reviews and Meta-analyses (PRISMA) checklist (27).

Inclusion and exclusion criteria

As suggested by the Cochrane Collaboration, the core constituents of the review question were divided into subheadings using the PICOS format (participant, intervention, comparator, outcome, and study type) (28).

Search strategy

A search of literature was conducted using the following six databases: Medline, Embase, PubMed, Web of Science, CINAHL, and Cochrane library. Search terms used include "laser" or "light" and "hair" or "hirsute" or "hirsutism" or "hypertrichosis" or "hyperandrogenism" or "hyperandrogenous".

Screening

PICOS criteria were used as a screening tool for assessing the suitability of papers obtained through online database search. Initially, the papers were screened by title, then by abstract, and finally by full text. After the screening was complete, a list of relevant papers for inclusion in the review was produced.

Data extraction and synthesis

Data extraction was carried out using an adapted version of the Cochrane Data Extraction form (29) (Table 1). Data were too heterogenous to be pooled for meta-analysis.

Bias analysis

Risk of bias was assessed by two independent reviewers using the Cochrane Risk of Bias Tool (30).

Critical appraisal

Critical appraisal of the final five papers was also conducted in duplicate using the GRADE tool (31).

Results

Literature search results

As depicted in Figure 1, a total of 893 papers were screened after removal of duplicates. Following title and abstract screening, 26 of these trials were retained for full-text review. Of these, 5 randomized controlled trials (RCTs) were deemed suitable for inclusion in this systematic review (32–36) (Figure 1). These trials included 223 patients in total: Nd:YAG laser (2 trials, 55 patients), Diode laser (3 trials, 97 patients); Alexandrite laser (3 trials, 111 patients), Ruby laser (0 trials), and IPL (3 trials, 103 patients) (Figure 1). Sample sizes ranged from 20 to 100 participants and skin types I–VI; all participants had brown-black hair. A summary of study characteristics can be found in Table 2.

Risk of bias assessment

Results of risk of bias assessment are summarized in Figure 2. The overall risk of bias in four of the five trials was unclear, with the remaining trial being low risk (35). Sequence generation and allocation concealment were concurrently adequately reported in only two (33,35) trials. Blinding of both participants and investigators was only adequately reported in three trials (32,33,35). Risk of attrition bias and reporting bias was judged as unclear in all five trials. Furthermore, three trials (32–34) were found to have high risk of selection bias.

Critical appraisal

Four (20–22,24) of the five studies were graded as moderate quality and one as low quality (23) for the outcome "long-term hair reduction" (Appendix 4).

Long-term hair reduction

All the five trials reported data on the primary outcome of interest: long-term hair reduction. Average hair reduction reported from trials of Nd:YAG laser (35,36) (n = 2) for short-term follow-up varied from 60–73.60% and long-term ranged from 30–73.61%. Diode laser was assessed in three trials (32,33,35) and resulted in average hair reductions of 59.7–70% in the short-term and 32.5–69.2% in the long-term. Average hair reduction in trials of Alexandrite laser (34,36) (n = 3) ranged from 52–85.99% in the short-term and 35–84.25% in the long-term. Three trials (32–34) investigated IPL with average hair reduction ranging in the short-term from 21–77% and in the long-term from 52.7–27%.

Table 1 :Data extraction form.

Author, Year	Laser Types	% Mean Reduction in Hair Count from baseline at LAST follow-up ± SD				% Mean Reduction in Hair Count from baseline at FIRST follow-up ± SD				Average Patient Satisfaction Scores	
Adverse Effects (%)						Mean Pain Score ± SD (scale)					
Immediate Erythema (%)	Hypopigmentation (%)	Hyperpigmentation (%)				Blistering (%)			Superficial Burn (%)	Burning Sensation (%)	Scarring (%)
Davoudi, 2008	Nd:YAG	73.61% ± 11.4			Digital camera	73.60% ± 16.6			p = 0.26	NS	NS
	12mm Alexandrite	75.89% ± 19.0			p = 0.25	79.6% ± 19.59					
	18mm Alexandrite	84.25% ± 12.4			Visomed AG device	85.99% ± 11.62					
	Alexandrite + Nd:YAG	77.81% ± 15.9			p = 0.65	79.61% ± 18.1					
Galadari, 2003	Nd:YAG	3 sessions	6 sessions	Average	NS	3 sessions	6 sessions	Average	NS	NS	NS
	Alexandrite	25%	35%	30%		50%	70%	60%			
	Diode	30%	40%	35%		50%	80%	65%			
		25%	40%	32.5%		60%	80%	70%			
Haak, 2010	Diode	34%			p = 0.427	68%			p = 0.277	50%	p = 0.125
	IPL	40%				77%				60%	
Klein, 2013	Diode	69.2%			**p ≤ 0.01***	59.7%			**p ≤ 0.01***	NS	NS
	IPL	52.7%				42.4%					
McGill, 2007	Alexandrite	46%			**p< 0.001***	52%			**p < 0.001***	7.7/10	**p ≤ 0.002***
	IPL	27%				21%				5.1/10	

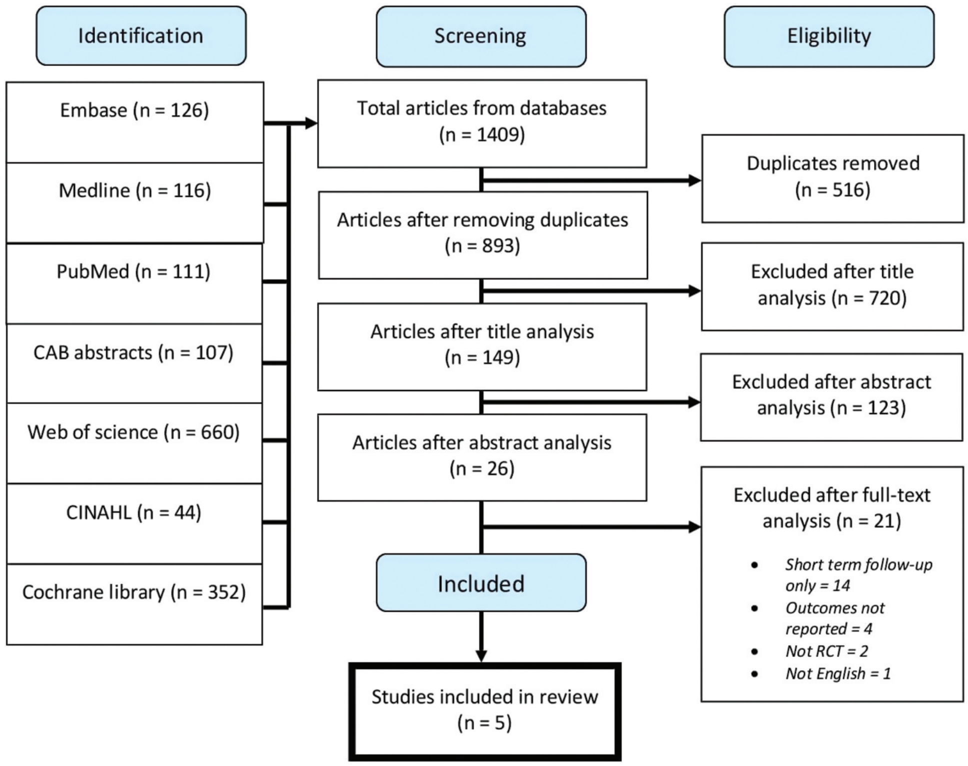

Figure 1. Literature search protocol.

Among the five trials included; Davoudi *et al.* (35) performed a within-patient RCT on 20 volunteers of skin types III–IV to compare lasers on hair removal in the leg area including Nd:YAG, 12 mm; Alexandrite,18 mm; Alexandrite, and a combination of Alexandrite+Nd:YAG. Follow-up was 18 months post-final treatment and showed greater long-term hair-count reduction using 18 mm Alexandrite (84.25%), followed by 12 mm Alexandrite (75.89%) then Nd:YAG (73.61%); however, these differences were non-significant ($p = .25$). Galadari *et al.* (36) also performed an RCT comparing Nd:YAG, Alexandrite, and Diode in 100 volunteers of skin types IV–VI, with treatment directed to the face. Again, 12-month follow-up showed superior long-term hair-count reduction using Alexandrite (35%) followed by Diode (32.5%) then Nd:YAG (30%); however, statistical tests and drop-out rate were not reported; thus, data were difficult to interpret. Haak *et al.* (32) completed a within-patient RCT on 35 volunteers with skin types III–IV to compare Diode laser against IPL, with treatment directed to the face. Six-month follow-up showed greater but non-significant ($p = .427$) long-term hair-count reduction by IPL (40%) compared to Diode (34%). Klein *et al.* (33) also compared Diode to IPL in a within-patient RCT of 30 volunteers with skin types I–III with treatment targeted at the axillary area; however, comparatively, their 12-month follow-up showed that Diode (69.2%) produced a significantly greater ($p \leq .01$) long-term hair-count reduction than IPL (52.7%). McGill *et al.* (34) performed a within-patient RCT on 38 volunteers with PCOS and skin types I–IV to compare Alexandrite laser against IPL with treatment directed to the face. Six-month follow-up showed significantly greater ($p < .001$) long-term hair-count reduction by Alexandrite (46%) compared to IPL (27%).

Discussion

Review of the five RCTs included in this review did not demonstrate superiority of one laser or light device over another; however, it did provide evidence suggesting that hair-cycle lengths of specific sites should be considered when evaluating long-term efficacy of lasers and light devices in hair reduction for problematic hair. Notably, there was only a small number of total participants in the five trials included in this review, and despite all being RCT, none were deemed to be of high methodological quality, so it may be that the question of actual efficacy of laser and photo-epilatory devices cannot be answered until high quality trials are published.

The average hair reduction reported from trials of Nd:YAG laser (n = 2) for short-term follow-up varied from 60 to 73.60% and long-term ranged from 30 to 73.61%. The trial reporting both greatest short-term and long-term efficacy (35) focused on treatment of leg hair vs the other trial focused on treating the facial area (36). As leg hair has a longer growth cycle (1-year) compared with the face (6-months) (22), this may account for the greater reduction of hair seen in this trial. Interestingly, one trial (36) implemented different numbers of treatment sessions between groups and found that increasing

Table 2 :Summary of study characteristics.

Author, Year	Trial Type	Population	Sample Size	Age, mean (range)	Female, No. (%)	Skin type (%) I	II	III	IV	V	VI	Anatomical location (hair colour)
	Laser Settings											
Laser Types (population number)	Wavelength (nm)	Energy (J/cm^2) *= J/cm^3	Pulse Duration (ms)	Spot Size (mm)	No. of sessions, intervals	Control	Method used to assess hair-reduction	Setting (Month)	No of months from last treatment to first follow-up	No of months from last treatment to last follow-up	No of Dropouts (%)	Main findings
Davoudi, 2008	Within-patient RCT	Volunteers with skin type III–IV	20	32.6 (16-50)	11 (55)	0	0	15 (75)	5 (25)	0	0	Legs (black)
Galadari, 2003	RCT	Females with skin type IV–VI	100	NS	100 (100%)	0	0	0		NS		Upper lip, face (black)
Haak, 2010	Within-patient RCT	Hirsute women with intrinsically normal or medically normalized testosterone levels; skin type IV–V	35	38 (19-59)	35 (100)				NS		0	Face (brown, black)
Klein, 2013	Within-patient RCT	Fitzpatrick skin type I–III and brown to black axillary hair	30	33.7 (21–50)	30 (100)	0	18 (60)	12 (40)	0	0	0	Axilla (brown, black)
McGill, 2007	Within-patient RCT	Women with diagnosis of PCOS; Fitzpatrick skin types I–IV	38	34 (16-69)	38 (100%)		34		4	0	0	Face (brown, black)

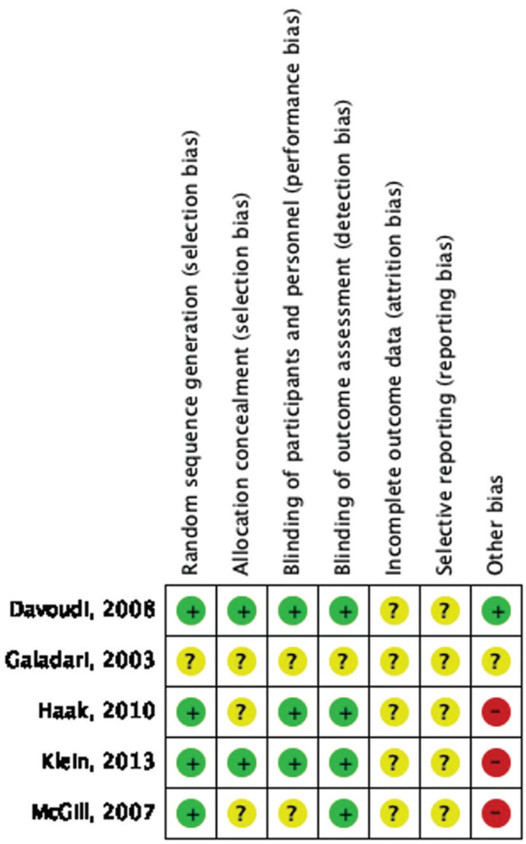

Figure 2. Risk of bias assessments.

treatment sessions from 3 to 6 improved percentage hair reduction by 20% short-term and 10% long-term; hence, number of treatments may also affect efficacy.

Diode laser was used in three trials and resulted in average hair reductions of 59.7–70% in the short-term and 32.5 69.2% in the long-term. The trial that reported the lowest short-term and highest long-term reduction targeted legs (33). This anomaly may be explained by the theory that the sensitivity of hair follicles to laser pulses varies depending on growth-cycle phase (37). Dierickx *et al.* (37) found that after one treatment, hairs "resistant" to laser damage were mainly in the telogen phase at the time of exposure, indicating that further research is required. The trial that reported the highest short-term hair reduction and the lowest long-term hair reduction targeted the face (36), again supporting the idea that efficacy of devices in hair reduction may depend on the growth-cycle length of the hair targeted. While both of these trials used 800 nm Diode laser, there was much variation in fluences, pulse durations, and spot sizes used between trials varying from 20 to 40 J/cm^2, 20 to 150 ms, 9 to 12 mm, respectively, making it difficult to isolate one individual cause for the results seen and, hence, the need for future trials to standardize laser parameters.

Average hair reduction in trials of Alexandrite laser (n = 3) ranged from 52 to 85.99% in the short-term and 35 to 84.25% in the long-term. The trial that reported the lowest short-term and long-term hair reduction targeted the face (34). The trial that reported the highest short-term and long-term reduction targeted the legs (35). Again, this may be explained by the fact that the leg area has a longer hair growth-cycle duration compareed to the face (22).

Average hair reduction from IPL trials ranged from 21 to 77% in the short-term and from 52.7 to 27% in the long-term. The lowest short-term and long-term hair reduction came from a trial targeting the face (34). The highest short-term reduction in hair came from a trial by Haak *et al.* (32), which also targeted the face, and the highest long-term reduction in hair came from the Klein *et al.* (33) trial, which targeted the axilla. Haak *et al.* (32) found that IPL produced greater long-term hair reduction than Diode long-term; however, Klein *et al.* (33) found the reverse, and the latter is supported by a randomized split-body comparison of IPL with Diode laser by Sochor *et al.* (38). A comparison study by Chen *et al.* (39) also compared the efficacy of Diode laser with IPL for hair but found no statistically significant difference in hair reduction between the Diode laser and IPL. Therefore, there is much conflicting data on this outcome, and more research is needed.

There have been many non-RCTs (39–45) and RCTs (38,46–51) on the efficacy of laser and IPL-based hair removal previously, most of which only follow participants short term (39,41,42,45). There is evidence that some trial (51) definitions of "long-term" hair reduction fail to take into account the site-specific periods of hair growth cycles of the areas they measured long-term hair reduction for. An RCT by Handrick *et al.* (51) targeted underarm hair with follow-up 6 months from last treatment; however, the growth-cycle for under-arm hair has been found to be 7 months (22); therefore, follow-up at 6 months cannot provide a true measure of "long-term" hair reduction. There was heterogeneity in body site treated in some trials including Lin *et al.* (41), who compared 694 nm Ruby with 800 nm Diode and targeted abdomen, buttock, back, shoulder, forearm, upper arm, thigh, and lower leg. As these areas have different growth-cycle lengths, it is difficult to compare long-term efficacy of devices. The trials implemented varying device parameters and treatment protocols with different numbers of treatment sessions at different intervals (weeks to months). There was also widespread variation in participant characteristics with regards to skin and hair color, anatomic region treated, and endocrine system function, which may also impact treatment outcomes. While all trials in this review only included people with dark hair and some even selected for this (32–34), a non-randomized trial by Rao *et al.* (43) found that participants with red or light-colored hair saw 5–15% less efficacy in hair reduction with any laser system used compared with dark-haired participants; thus, the findings from the small number of trials suitable for inclusion in this review are not generalizable to the wider population.

Conclusion

Nd:YAG, Diode, Alexandrite, and Ruby lasers, as well as IPL devices, have all been previously studied and shown to be valuable in the short-term for hair-reduction with varying risk of adverse events. Analysis of the five long-term RCTs included in this review did not indicate a clear pattern of superiority of one laser or light device over another in terms of efficacy or safety. Of note, however, is that in all three trials where Alexandrite was compared to other devices, it produced the greatest long-term hair reduction in each case. Non-standardized treatment protocols, including variations in device energy settings, pulse-width, number of treatments, and body-site targeted made it impossible to determine whether a dose–cause relationship for any individual parameter was present. However, targeting anatomic regions with longer hair growth cycles, such as the legs, appeared to result in greater long-term reduction in hair growth, therefore fitting with the theory that the assessment of efficacy of laser and light devices in long-term hair-reduction should adjust for site-specific growth-cycle lengths.

Implications for future research

There is growing demand for high-quality trials with regards to outcomes related to laser and photo-epilation. Especially needed are trials with truly long-term evaluations of efficacy using site-specific measurements of hair re-growth based on knowledge of length of hair growth cycles. Moreover, prospective trials must standardize treatment protocol for all parameters, including number of treatment sessions, treatment interval, treatment location, and device settings to produce comparable data evaluating the safety and efficacy of devices across patients. There is also a lack of trials evaluating the efficacy of lasers and IPL versus untreated controls and trials comparing all four lasers (Ruby, Alexandrite, Diode, and Nd:YAG) and IPL within the same group of participants, which is important to reduce the effect of within-participant variables on outcome measures. The effects of participant characteristics on individual hair-removal outcomes remain broadly unclear, and an increase in trials investigating patient-specific variables may allow practitioners to apply a more strategic and personalized approach to treatment of unwanted hair, in addition to providing more accurate information for the general public considering undergoing these treatments. Overall, larger, prospective, blinded RCTs with longer follow-up and including patients of all skin types and uniform treatment protocols are necessary to fully understand the long-term efficacy of lasers and IPL devices in hair reduction.

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Supplementary materila

Supplemental data for this article can be accessed here.

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