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Laser hair removal pearls

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REVIEW ARTICLE

Laser hair removal pearls

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Abstract

A number of lasers and light devices are now available for the treatment of unwanted hair. The goal of laser hair removal is to damage stem cells in the bulge of the follicle through the targeting of melanin, the endogenous chromophore for laser and light devices utilized to remove hair. The competing chromophores in the skin and hair, oxyhemoglobin and water, have a decreased absorption between 690 nm and 1000 nm, thus making this an ideal range for laser and light sources. Pearls of laser hair removal are presented in this review, focusing on four areas of recent development: (1) treatment of blond, white and gray hair; (2) paradoxical hypertrichosis; (3) laser hair removal in children; and (4) comparison of lasers and IPL. Laser and light-based technologies to remove hair represents one of the most exciting areas where discoveries by dermatologists have led to novel treatment approaches. It is likely that in the next decade, continued advancements in this field will bring us closer to the development of a more permanent and painless form of hair removal.

Key words: *Lasers, Hair Removal*

Laser hair removal: background

A number of lasers are now available to successfully eliminate unwanted hair. Ruby lasers were the first to be applied (1,2); however, there is now a wide array of lasers including alexandrite, diode and neodymium-doped yttrium aluminum garnet (Nd:YAG) as well as a variety of broad spectrum intense pulsed light (IPL) devices.

The goal of laser hair removal is to damage stem cells in the bulge of the follicle or to replace the hair follicle at the level of the dermis with connective tissue through thermal injury (3,4). The primary mechanism of laser hair removal is 'selective photothermolysis' whereby follicular melanin is the target chromophore for destruction by light energy (5–7). In order to selectively target and damage the hair follicle, laser energy has to be absorbed by an endogenous chromophore (melanin in the case of the hair follicle) within a period which is less than or equal to the thermal relaxation time of the follicle (8).

Melanin absorbs light broadly across the optical spectrum. The competing chromophores in the skin and hair, oxyhemoglobin and water, have a decreased absorption between 690 nm and 1000 nm, making this an ideal range for a laser targeting melanin in the hair follicle. While melanin absorbs better at 690 nm than at longer wavelengths, penetration of light is deeper at longer wavelengths, thus reaching the bulb and matrix region of the hair follicle with greater efficacy. The other complicating factor with laser hair removal is that in darker skin types there can be absorption by epidermal melanin resulting in significant epidermal damage. This complication can be overcome by applying the concept of 'thermokinetic selectivity', whereby target structures of large volume such as hair shafts are unable to transmit absorbed energy to surrounding structures (9,10). By selecting the appropriate pulse length, the thermal damage may be concentrated in the larger target structures (follicular papilla, germinative cell layer and bulge area) (11). The ideal pulse duration in laser hair removal is approximately 10–50 ms, which lies between the thermal relaxation time for the epidermis (3–10 ms) and that for the hair follicle (40–100 ms) (12). Both 'selective photothermolysis' and 'thermokinetic selectivity' are postulated to explain the mechanism of laser hair removal with the ruby (13), alexandrite (14), diode (15),

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Q-switched Nd:YAG (16) as well as IPL source devices (17).

Treatment of white, blond and gray hair

Laser hair removal of white, blond and gray hair is often unsuccessful due to the lack of melanin, the chromophore targeted by the laser. Greater success of long-term laser hair removal has been shown to correlate with the amount of eumelanin pigment in the hair follicle (18).

Recently, attempts at removing non-pigmented hairs with a combined light/bipolar radiofrequency device with or without pre-treatment with a topical photosensitizer have shown success. Goldberg et al. performed a study analyzing the effects of a combined pulsed light bipolar radiofrequency device with and without pre-treatment with topical aminolevulinic acid in the removal of non-pigmented hair (19). An average terminal white hair removal of 35% was observed at 6 months after treatment. With pre-treatment with topical aminolevulinic acid, the average hair removal of terminal white hairs was 48%.

Sadick and Laughlin performed a similar study to evaluate the removal of blond and white hair with a combined IPL (680–980 nm) device with a bipolar radiofrequency component in the absence of a photosensitizer (20). At 6 months after the series of four treatments, the average hair removal was 48%. When comparing the results of these two studies, it should be noted that the combined radiofrequency device utilized with two treatments in combination with aminolevulinic acid by Goldberg et al. gave the same improvement in non-pigmented hair (48% reduction) as four treatments in the absence of a photosensitizer by Sadick et al. (48% reduction). These results suggest that photosensitizers augment the effects of combined radiofrequency devices in non-pigmented hair reduction.

A recent alternative approach to treat white, blond and gray hair with laser hair removal has been the external application of melanin to the hair through the use of liposome technology. Liposomes are phospholipids, which are the biologic lipids of cell membranes which spontaneously adopt bilayers in water (21). Melanin-encapsulated liposomes have demonstrated to selectively deliver melanin to the follicle and hair shaft (22).

De Leeuw et al. published the first study utilizing melanin-encapsulated liposomes to improve laser hair removal of non-pigmented hair (21). Lipoxome® spray was applied for 14 days, with application six to eight times per day prior to a series of eight to ten laser treatments with an 800-nm diode laser. At 6 months after the last laser treatment, 90% of patients experienced a permanent hair reduction of over 75% within 10 treatments and 62.5% of patients experienced a reduction of 95–100% with an average of eight treatments. Interestingly, they found a correlation between the quantity of Lipoxome applied to the area in the 14-day pre-treatment period and the extent of laser hair removal (correlation coefficient 0.785, significance level of 99.9%). Histological studies were also performed after application of Lipoxome which confirmed the presence of new deposits of melanin in the hair follicle after application.

A comparative study by Sand et al. found less promising long-term hair removal with the use of liposome technology in combination with the 800-nm diode laser for hair removal. In this study, patients were pre-treated with Lipoxome 12 times daily for 8 weeks prior to each of a series of three laser treatments (23). At 8 weeks after the last treatment, patients in the Lipoxome group had a decrease in hair density of 17% compared with a 13% decrease in the control group. At 6 months after the last treatment, patients in the Lipoxome group had a 14% reduction in hair density compared with a 10% reduction in the control group.

Owing to variability in efficacy of the liposomal melanin spray reported in these two studies, its application use for laser hair removal of non-pigmented hair requires further evaluation.

Paradoxical hair growth after laser hair removal

Several experts in laser hair removal have noted a rare but striking paradoxical effect whereby some patients have increased hair growth at sites previously treated for hair removal. In a recent review, Goldberg cited that this effect tends to occur more frequently in patients of skin types III or higher, more commonly with IPL and in an adjacent area of untreated skin (24). In addition, the effect has also been reported in individuals with previously undiagnosed hormonal conditions, such as polycystic ovarian syndrome, emphasizing the importance of history taking and proper patient selection in laser hair removal. The etiology of this effect is unclear but some have speculated that it is lower-range fluences of laser and light in individuals with darker skin types which paradoxically stimulates hair growth. Prevention and treatment of the induced hair growth has emphasized the use of higher fluences.

In the first report by Moreno-Arias et al., 49 female patients were treated for facial hirsutism with an IPL light source (EpiLight™, ESC, Israel) (25). A paradoxical effect of new fine and dark hair in untreated areas in close proximity to the treatment areas (such as the neck) was reported in five out of 49 patients. The authors suggested that suboptimal fluences may have caused the paradoxical effect on the hair follicles. A second study performed by

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Moreno-Arias et al. evaluated the clinical and hormonal characteristics of these five patients who developed this 'paradoxical effect' of hair growth in untreated areas (26). On laboratory and clinical analysis of these patients, all five were diagnosed with polycystic ovarian syndrome and presented with ovarian hyperandrogenism. The authors concluded that IPL may induce areas of growth in dormant hair follicles in untreated areas adjacent to hirsute-treated areas, particularly in patients with hyperandrogenism.

The second report of paradoxical hypertrichosis was reported by Hirsch et al. in 14 patients who were treated with a long-pulse 755-nm alexandrite laser (27). The authors found that all of their patients with hypertrichosis had darker skin types (III–V), 93% were female and 86% grew hair on the side aspect of the face.

Kontoes et al. reported the results of the largest retrospective analysis of 750 patients (737 female, 13 male) in their private practice in Greece who underwent laser hair removal between 1998 and 2005 to assess the incidence of paradoxical hair induction (28). The overall incidence was 4.5% (30/750) and occurred most frequently on the face and neck (28/30 cases) of females. Patients experiencing the effect were all of Mediterranean ancestry with darker skin types (III–IV), indicating a greater tendency for transformation from vellus to terminal hair in such skin types. At least three treatments were performed before the patients noticed hair induction and hair induction was seen in all laser and light treatment sources (IPL, long-pulsed alexandrite laser or both). Only one patient reported having an underlying hormonal condition, polycystic ovarian syndrome, and one other patient was receiving corticosteroid treatment for an underlying autoimmune condition. In all patients who elected to continue receiving treatments in the previously treated areas as well as in the areas of new induced hair growth, the terminal hair responded well to therapy. The authors speculated that as hair induction occurred primarily at the border of the treated area in the adjacent untreated skin that it is possibly low levels of energy or local inflammation which results in the paradoxical induction of hair in individuals of darker skin types (III–IV).

An additional case series by Alajlan et al. of a retrospective study of 489 patients treated with the long pulse 755-nm alexandrite laser between June 1999 and June 2003, identified three patients (0.6%, confidence interval 0.01–1.9%) who experienced a paradoxical increase in hair growth after laser hair removal (29). All three patients who experienced paradoxical hypertrichosis after laser hair removal were treated with a fluence (27.5 J/cm^2) at the lower end of the effective standard range of fluences.

Vlachos et al. reported two cases of increased terminal hair which developed after one port wine stain and one tattoo were treated several times with an ILP source (30). The first case occurred in a 22-year-old man, skin type IV, who presented for removal of tattoos on his calf, right arm and entire back. No sex hormone abnormalities were identified in either patient and the pattern of hair growth in either patient did not resemble hirsutism, hypertrichosis or normal age-related development of terminal, pigmented hair. The authors noted that terminal hair development in both patients occurred several months after an intense inflammatory response to IPL and that both patients were of darker skin types.

Postulated contributing factors to this 'paradoxical effect' of increased hair growth in response to laser and light photoepilation presented in these case reported include underlying previously undiagnosed hormonal conditions (such as polycystic ovarian syndrome and associated ovarian hyperandrogenism) and hormone supplements/medications inducing hypertrichosis (corticosteroids, finasteride), incidence of vigorous laser/IPL post-treatment side effects (erythema, crusting, edema, hyperpigmentation), treatment with sub-optimal fluences (where there is insufficient light energy to destroy melanocytes in the matrix of the follicle), anatomical site and gender (face and neck of women were most likely) and skin types III–VI (as a result of the greater likelihood of a shift between vellus and terminal hair in patients of darker skin types).

Laser hair removal in children

Unwanted hair in the pediatric population is often due to either localized or generalized hypertrichosis or to congenital hairy nevi (31). Hypertrichosis in children prior to puberty, unlike hirsutism in adults, is not associated with an underlying endocrinological condition and is typically classified based upon the age of onset (congential versus acquired) and the distribution (localized or generalized). In its localized form, symmetrical areas of hypertrichosis may occur in particular anatomical sites such as the elbows (hypertrichosis cubiti), anterior cervical region, posterior cervical region or faun tail deformity. In its generalized form, hypertrichosis typically presents as an isolated finding, as in hypertrichosis lanuginosa congenita or in association with gingival hypertrophy.

Hair removal methods include a wide array of modalities including bleaching, shaving, waxing, electrolysis, physical and chemical depilatories and IPL and laser depilation. Many of these modalities are of lesser applicability in children given the time commitment, potential systemic toxicity, extensive pain and potential side effects of folliculitis, post-inflammatory erythema, edema and hyperpigmentation. Laser and light-based modalities, such as the ruby, alexandrite, diode and Nd:YAG as well as IPL

devices have not been investigated extensively in children.

In 2002, Morley and Gault reported a series of 28 cases of patients aged 16 or under who underwent treatment with the long-pulsed ruby laser for unwanted hair in a plastic surgery unit (32). The device utilized was a flashlamp pumped ruby laser (694 nm) with a spot size of 5 mm and fluences between 6.5 and 19.5 J/cm^2. No skin cooling mechanism was utilized. The conditions treated included: one Becker's nevus, four cases of unwanted hair in isolation (two face, two arms), three cases of unwanted hair growth at the site of an ear reconstruction covered by scalp skin, one case of a pilonidal sinus and one case of hair arising at the site of anotia. Treatment was a success in 25 out of 28 patients, where there was a clear reduction in hair growth at the site treated, with an average decrease in hair count of 63% at 6 months follow-up after treatment. Permanent hair removal was not achieved in any of the patients treated. For the three patients without significant improvement, two of these patients had blond hair. The only complication was temporary blistering of a treated congenital hairy nevus which settled with conservative management.

In a case series of the diagnosis and management of 11 pre-pubertal patients with hypertrichosis by Vashi et al., three children had generalized hypertrichosis with onset at birth and no associated medical problems, with soft and silky blond to brown hair which was diagnosed as hypertrichosis lanuginosa acquisita. One child had diffuse coarse brown hypertrichosis and associated developmental delay and gingival hyperplasia, suggesting the diagnosis of gingival fibromatosis and hypertrichosis. The remaining seven children all had localized hypertrichosis. All 11 patients, except two with anterior cervical hypertrichosis attempted treatment, with either chemical depilatory treatment or trimming. Only the patient with generalized hypertrichosis and gingival hyperplasia with dark brown coarse hair tried IPL therapy but found it too painful and costly, and thus switched to chemical depilatory treatment. The parents in this study considered the treatments for localized hypertrichosis with chemical depilatory treatment or trimming to be satisfactory; however, the parents of children with generalized hypertrichosis found electrolysis and IPL to be too painful and costly.

Cheung and Lanigan reported a case of a 10-year-old girl successfully treated for nevoid hypetrichosis using an alexandrite laser (33). This patient had a history of a patch of terminal hair growth on her upper back soon after birth. All studies to evaluate for spinal dysraphism were within normal limits. The patient underwent a series of five treatments with the 755-nm alexandrite laser for 2 months with resultant significant resolution of the lesion and a continued decrease in hair density at 4 months post-treatment. The laser treatment was well tolerated by the patient and pain was minimal with the application of EMLA cream 30 minutes before each session.

In 2002, Mahendran and Sheehan-Dare reported sustained improvement of similar congenital lumbosacral hypertrichotic lesions after treatment with the normal mode ruby laser (34). A total of seven female patients aged between 7 and 16 years, with no underlying associated spina bifida occulta, were treated with the ruby laser for three treatments at 2-month intervals. Two out of seven patients had a significant reduction in hair growth in the lumbosacral reigon that was sustained 6 months after the final treatment. Interestingly, one of these patients had light ginger-colored hair, but had an excellent response to ruby laser hair removal. Five patients had no visible change in their hair density at the conclusion of the treatment or at the 6-month follow-up interval.

Littler et al. evaluated the efficacy of the Q-switched Nd:YAG laser for hair removal in a patient with hypertrichosis lanuginosa congenita after the application of a topical carbon-based solution (35). A 40–80% reduction in hair counts was noted in all areas treated with this methodology with low and tolerable associated discomfort.

The primary complications of treating pediatric patients with laser hair removal include the lack of efficacy for blond or white hair, the lack of permanent hair removal as well as the pain associated with the treatment. In all studies there was little or no efficacy reported for the removal of non-pigmented hair in children, similar to the data in the literature for adults. Second, in all studies, the hair removal achieved was a temporary finding, lasting between 1 and 6 months, and many of the parents of the children treated were disappointed with the results as they were seeking a more permanent form of hair removal. While it was noted in many cases that when the hair grew back it was often finer, lighter in color and reduced in number, these results were often not satisfactory to the parents who were seeking complete hair removal. Finally, pain control was a significant issue in the pediatric population. The advent of new technology to reduce the discomfort associated with laser hair removal, such as pneumatic skin flattening (PSF) recently reported by Lask et al. (36), may have a significant impact on the tolerability and applicability of laser and light-based hair removal in the pediatric population.

Comparison of laser and IPL devices

IPL devices have been utilized for laser hair removal with overall similar rates of efficacy as laser devices but with less pain. IPL devices emit broad spectrum, non-coherent (non-laser) radiation of wavelengths between 550 nm and 1200 nm (37). A unique

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feature of IPL devices is the delivery of a pulse in a series of two to five mini pulses, the duration and delay of which can be customized within the millisecond range. Several spot sizes are available with IPL devices which can be selected based upon the anatomical site to be treated. Theoretically, these features of IPL should allow deep penetration of radiation with a uniform beam, facilitating the targeting of deeper follicles as well as coarse or thin hair while preventing epidermal damage to minimize erythema and dyspigmentation. Between three and eight treatments are needed at intervals of 4–8 weeks to successfully achieve long-term hair reduction (38). Under these treatment protocols, efficacy rates of 70–90% removal of hair with IPL devices have been achieved.

A variety of early studies demonstrated the efficacy of IPL for use in hair removal. Gold et al. published one of the earliest studies in 1991 of a study of 31 patients treated for 3 months with IPL for hair removal (39). A total of 24 of the 31 patients participating in the trial were subsequently examined at 1 year following treatment for evaluation of the long-term efficacy of hair removal. Long-term removal of 75% of the hair in the treated areas was observed after a single treatment.

Troilius and Troilius evaluated the use of IPL in the removal of hair from the bikini line area (40). A total of 10 females with dark hair and skin type II–IV were treated with a second generation IPL source (600 nm) four times within a 1-month interval. Hair follicle counting was performed using a computer imaging system prior to treatment at 4 and 8 months after treatment. Mean hair reduction was 74.7% (SD $\pm$ 18.3%) at 4 months after treatment and 80.2% (SD $\pm$ 20.3%) 8 months after the last treatment. Side effects were minimal and no pain or other discomfort was reported by the patients receiving treatment.

El Bedewi performed a study evaluating the efficacy of IPL for hair removal in a series of 210 patients from Egypt (Fitzpatrick skin type III–V) (41). All patients underwent three to five IPL treatments with 6 weeks between each treatment. Follow-up evaluation of the decrease in hair was performed at 6 months after the final treatment. The settings utilized were a fluence of 25–40 J/cm^2, pulse duration of 50–80 ms, with a cut-off filter of 615 nm with a double pulse illumination. The mean reduction in hair density over all patients at 6 months after treatment was 80%. While most patients had transient erythema and perifollicular edema immediately after the procedure, no post-inflammatory hyper or hypopigmentation, scarring or burn were detected.

Several comparative studies have recently been published comparing the efficacy of the side-effect profile of IPL with ruby, alexandrite, diode and Nd:YAG lasers. Amin and Goldberg performed a recent comparison study in 2006 comparing the decrease in hair counts with four devices: (1) an IPL with a red filter: Palomar, Starlux RS, 65 J/cm^2; (2) an IPL with a yellow filter: Palomar, Starlux Y, 35 J/cm^2; (3) an 810-nm diode laser: Lumenis, Lightsheer, 28 J/cm^2; and (4) a 755-nm alexandrite laser: Candela, Gentlelase, 18 J/cm^2 (42). A total of 10 patients were treated twice with each device on the back and hair counts were taken at 1, 3 and 6 months after the final treatment. There was a 50% decrease in hair counts and 55% decrease in hair coverage in evaluation of photographs at day 210 of the study. After two treatments with all devices a decrease in hair coverage was detected; however, no statistically significant differences between devices were detected. There were no statistical differences in hair removal efficacy between the four different light devices. Both IPL II (Palomar, StarLux Y, 35 J/cm^2) (2.1) and diode (2.3) had the lowest pain scores of all devices; in contrast, higher pain scores were given to IPL I (Palomar, StarLux RS, 65 J/cm^2) (3.4) and the 755-nm alexandrite laser (4.1). The first three devices with contact cooling all had lower pain scores than the alexandrite laser with a cryogen spray cooling.

A second right/left comparison study was performed by Bjerring et al. in 2000 to compare the effectiveness of IPL with a normal mode ruby laser for hair removal (43). A total of 31 patients were treated three times with an IPL system on one side of the chin and neck and three times with a normal mode ruby laser on the other side. After 6 months, nine of the patients received three additional IPL treatments and 11 patients received three additional ruby laser treatments. Hair reduction was seen in 93.5% of treated sites after three IPL treatments and only in 54.8% of ruby laser-treated sites. For the additional laser treatments, in those patients who had previously received IPL, three IPL treatments only resulted in a further reduction of 6.6%; however, for patients who had previously received ruby laser, three additional IPL treatments resulted in a further reduction of 35.5%.

A third comparative study by Goh compared the efficacy of the long pulse Nd:YAG laser with IPL for hair removal on darker skinned individuals (skin type IV–VI) (44). A total of 11 patients with skin type IV–VI were treated for hypertrichosis on the face, axilla and legs where one half of the body was treated with one treatment of long pulse Nd:YAG laser and the other half was treated with one treatment of IPL. A greater proportion of patients experienced hair reduction of $< 20\%$ on the Nd:YAG treated side (8/11, 73%) versus the IPL treated side (7/11, 64%).

Conclusions

The data presented herein represents a discussion of four areas of laser hair removal in which there have

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been many exciting recent developments in the technology to remove unwanted hair as well as in the identification of future avenues of exploration to continue the advancement of this field of science.

The treatment of non-pigmented hair has been, until recently, largely unsatisfactory given that previous laser and light-based technology are based upon selective targeting of melanin. The treatment of non-pigmented hair has recently grown with the advent of combined pulsed light bipolar radiofrequency devices alone and in combination with topical photosensitizers, whereby efficacy rates of 50% removal of hair in affected areas have been achieved. In addition, the application of liposome technology, where molecules with poor epidermal penetration, such as melanin, can be delivered through the skin, represents an exciting advance in the efficacy of laser hair removal as well as in the treatment of hair pigmentation disorders. Laser hair removal in children has been a more limited application of this technology, given the pain associated with treatment as well as the cost associated with the frequent treatments needed to achieve widespread and long-term hair removal. As there are many pediatric conditions affected by focal and diffuse hypertrichosis (congenital nevi, hypertrichosis lanuginosa acquisita, localized hypertrichosis – such as in lumbosacral, elbow and neck regions), laser hair removal represents an important treatment avenue. With the adjunctive use of topical anesthesia and exciting new advancements which decrease pain associated with laser hair removal (such as pneumatic skin flattening and hair removal by IPL), it is anticipated that laser hair removal will expand in children. Paradoxical hypertrichosis is a rare side effect that has received more recent attention in the literature as a consequence of laser and light-based hair removal. Through proper patient selection and the utilization of appropriate settings (identified cases are correlated with low–normal fluences in individuals with darker skin), this cosmetically undesirable side effect can be avoided. Finally, a comparative analysis of IPL and laser-based treatments for hair removal revealed high equivalent rates of efficacy for both techniques in terms of hair reduction and duration and improved pain control with IPL hair removal.

The current technology of laser and light-based technologies, when in the hands of a well-trained dermatologist physician, has advanced our ability to remove hair in patients with a variety of skin types, hair colors and textures with minimal side effects. It is likely that in the next decade continued advancements in the field of laser and light-based technology will bring us closer to the development of a more permanent, painless and universal hair removal approach.

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