

Triple Wavelength and 810 nm Diode Lasers for Hair Removal: A Clinical and *in Silico* Comparative Study on Indian Skin

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Abstract

In laser hair removal treatments on dark skin, the high concentration of melanin in the skin competes with the melanin in the hair. During standard laser procedures, with wavelengths of 755 nm or 810 nm, a high level of laser light absorption by melanin in the skin is observed. Therefore, to avoid side effects, lower fluence values are used, which further reduces hair-removal efficacy. To improve results, 810 nm diode lasers operating in dynamic mode, with high frequency and multiple passes, are typically used. The aim of this study is to compare the efficacy and safety of triple-wavelength diode lasers (810 nm, 940 nm, 1060 nm) with that of 810 nm diode lasers on Indian patients. A side-by-side comparison was performed using a triple-wavelength diode laser in stamping mode on one side, and an 810 nm diode laser in dynamic mode on the other. Three subjects with skin type IV on the Fitzpatrick scale participated in the study. Efficacy was assessed through hair counting using clinical photographs, taken before and after the treatments, and the Global Aesthetic Improvement Scale (GAIS). Additionally, comparisons related to epidermal heating and thermal damage to the hair follicle were conducted through mathematical 3D simulations using COMSOL Multiphysics[®] software. Side effects were also evaluated. A superior end point was observed with triple wavelength compared to the 810 nm diode laser. Hair counting showed a 27% greater hair reduction with triple wavelength. No adverse effects were observed. Thermal simulations revealed 29% higher thermal damage with the triple-wavelength laser compared to the 810 nm diode laser. To conclude, on darker skin types, the triple-wavelength diode laser has been shown to be more effective at removing hair, compared to the 810 nm diode laser, while also being a safe procedure.

Keywords

Photoepilation, Diode Laser Hair Removal, Triple Blend Wavelength, 810 nm, Comsol Simulations

1. Introduction

One of the most popular permanent hair removal techniques in modern society is laser photoepilation. This technique is based on the principle of selective photothermolysis and consists of applying laser light to the area being treated. The laser light is absorbed by the specific chromophore melanin, which transforms this energy into heat. This interaction results in thermal damage that directly affects the stem cells in the bulge region of the hair follicle [1] [2].

Since the arrival of the Alexandrite solid-state laser developed in the late 1990s, versatile devices and equipment have been created and improved over the years, achieving effective and safe results in hair removal applications on all skin types. Technological development has mainly been focused on hair elimination techniques for skin types with a higher melanin content (dark skin), due to the fact that the first lasers had problems with versatility. The main issue was that these lasers emit single and short wavelengths (755 nm and 810 nm), making them suitable for subjects with light skin, but not for subjects with skin with a high melanin content [3]. Nowadays, the main devices on the market that are used for photoepilation have wavelengths of 755 nm, 810 nm and 1064 nm [4].

Currently, 810 nm diode laser technology is one of the most widely used methods for the permanent elimination of unwanted hair, confirming itself as an effective and safe modality [5] [6]. However, on darker skin it is necessary to use low fluence values to avoid adverse effects on the skin, since the melanin of the epidermis competes with the melanin of the hair follicle, thus absorbing the light of the diode laser. Unfortunately, using lower fluences in the procedure reduces the efficacy of the treatment. To improve efficacy, the procedure can be performed in dynamic mode, at a high repetition rate and with multiple passes, in order to accumulate energy dynamically in the treated area [2] [7] [8] [9]. However, when compared with the standard stamping mode hair-removal method, the dynamic mode has the disadvantage of being highly operator dependent and time consuming.

To improve the efficacy and safety of treatments on dark-skinned subjects, devices that incorporate higher wavelengths have been developed, which allow lower absorption by the melanin and greater penetration into the skin. The longer the wavelength, the lower the absorption of light by the skin's melanin and therefore the lower the heating of the skin. This allows higher fluences to be used in each treatment, thereby increasing efficacy without compromising safety [10]. The use of diodes that combine two or three wavelengths has also recently been employed [11]. The benefits of having several wavelengths are less heating of the

skin and a deeper and more uniform heating of the hair. Results have been published with the combination of 755, 810 and 1064 nm [12]. In other studies, triple wavelengths of 810, 940 and 1064 nm have been used [13] [14] [15]. However, we have not found any study using triple wavelengths on Indian patients.

This study aimed to compare and evaluate the efficacy and safety of the triple-wavelength diode laser using 810, 940 and 1060 nm in stamping mode with that of a standard 810 nm diode laser in dynamic mode, on Indian patients with a dark skin type.

2. Materials and Methods

The study was conducted at the Escallent Institute, Gurugram, India. This is a single-center, side-by-side case report with a sample size of 3 subjects (2 males and 1 female) aged between 21 and 27 years (mean age 24 years, SD 3 years). Inclusion criteria were subjects with skin type IV, according to the Fitzpatrick scale, who had not previously been treated in the areas of study. In addition, subjects had to be willing to comply with all the study guidelines and procedures. Subjects who were pregnant or breastfeeding, those taking photosensitive medication or those with a photosensitive condition, skin pathologies or lesions or tattoos in the treatment area were not included.

One subject was treated on the abdominal area, one on the back, and the other on the arms. In all subjects, the right side was treated with the Primelase device (Cocoon Medical, Barcelona, Spain) using the triple-wavelength diode laser applicator (810 nm, 940 nm, 1060 nm) with 4000 W and a 2.7 cm² spot size, while the left side was treated with a MedioStar device (Asclepion, Jena, Germany) using an 810 nm diode laser with a 1.4 cm² spot size.

For the Primelase device, the parameters used were 20 J/cm², a pulse duration of 30 ms, a frequency of 1 Hz, and a single pulse (stamping mode). For the MedioStar device, the parameters used were 8 J/cm², a pulse duration of 16 ms, a frequency of 6 Hz, and multiple passes over the treatment area (dynamic mode). Epidermal cooling was performed in each session using an integrated cold sapphire in contact with the skin, which provided continuous contact cooling. A total of 3 to 6 sessions were performed at intervals of 8 to 12 weeks. No specific post-treatment care recommendations were given to the patients. They were advised to use broad spectrum sunscreen and avoid hot and humid conditions, sweating, friction, rubbing, cosmetics and salon procedures, 3 to 5 days post laser session.

Treatments were performed by a single technician.

The efficacy of each treatment was evaluated 6 months after the last procedure. Efficacy was evaluated by two independent investigators using hair counts (performed using high resolution digital photographs taken before and after treatment) and the GAIS scale, with hair reduction being rated between 1 and 5 points (1 = no reduction; 2 = <25%; 3 = 25% - 49%; 4 = 50% - 74%; 5 = >75%).

For the statistical analysis, the Excel package was used. The difference between

the two technologies was analyzed according to hair reduction percentage, expressed as the difference between the percentage hair reduction obtained using the triple-wavelength and 810 nm diode laser applicators:

$$\text{Hair reduction percentage} = \frac{\% \text{ Triple wavelength Diode} - \% \text{ Diode 810 nm}}{\% \text{ Diode 810 nm}}$$

The settings used were simulated by a 3D *in silico* mathematical model of hair and skin heating using COMSOL Multiphysics® [15]. In summary, the 3D model includes sapphire contact cooling at 10°C, along with epidermis, dermis, and hair follicle structure. A layer of hair-removal gel with a thickness of 0.3 mm between the sapphire and skin was also considered. The epidermis layer was set at 60 µm. The hair was divided into three zones: upper shaft, lower shaft, and bulb. Two different sheaths enveloping the hair were considered to calculate the effect on the cells in close proximity to the hair: one at 10 µm from the surface of the bulb to account for cells located on the bulb that are responsible for hair growth, and the other at 100 µm from the surface of the shaft to account for the stem cells located in the bulge. A thick and dark hair was considered in the simulations, with a depth of 3.5 mm, a shaft radius of 0.04 mm and a bulb radius of 0.14 mm.

The geometric model used in the numerical simulation was divided into a fine mesh in which the numerical equations for light diffusion, heat transfer and thermal damage were solved simultaneously to simulate the heating of the skin and hair follicle, as well as to determine the temperature and thermal damage for the skin and hair type of the subjects included in this study. The parameter of thermal damage was used to evaluate the efficacy of both devices and to compare it with the clinical results.

3. Results

Three subjects (2 men and 1 woman) aged between 21 and 27 years with Fitzpatrick skin type IV participated in this study. A comparative study was performed on the abdomen, arms and back using the triple-wavelength diode laser on the right side, and the 810 nm diode laser on the left side. Between 3 and 6 treatments were performed. Usually, 6 to 10 sessions are required for complete hair removal by diode lasers. It depends on the area of treatment, the characteristics of the hair of each subject and the laser parameters. However, in this study a smaller number of sessions were performed to focus primarily on the difference between safety and efficacy of these lasers.

Efficacy was assessed using digital images obtained before the first procedure and 6 months after the last treatment on each patient. The appearance of adverse effects immediately after each treatment was also assessed.

In the procedures using the triple-wavelength diode laser, a fluence of 20 J/cm² and a pulse duration of 30 ms were used in static mode (stamping mode and one pass), while in the procedures using the 810 nm wavelength, a fluence of 8 J/cm² and a pulse duration of 16 ms were used in dynamic mode (high repeti-

tion and multiple passes).

The pain reported by patients during the treatments was similar in both procedures.

Perifollicular erythema and edema were reported immediately after each treatment with both lasers; however, they were more pronounced in the area treated with the triple-wavelength diode laser (Figure 1). These transient effects were mild to moderate in all treated subjects and disappeared in 24 to 48 hours. No long-term adverse effects (burns, hyperpigmentation, depigmentation, or paradoxical hair growth) were reported on either side.

In all 3 treated subjects, greater hair reduction was observed in the areas treated with the triple-wavelength applicator, as shown in the hair counting and GAIS results (Table 1 and Figure 2).

Hair reduction of between 58% and 93% was achieved with the triple-wavelength diode laser, while the 810 nm diode laser achieved hair reduction of between 39% and 81%. According to these results, the triple-wavelength applicator removed between 10% and 59% more hair compared to the 810 nm diode laser applicator. On average, the triple-wavelength diode laser showed a hair reduction of 80% (SD 14%), while the 810 nm diode laser achieved a hair reduction of 66% (SD 19%), with the average improvement with the triple wavelength being 27% (SD 21%; $p = 0.0037$).

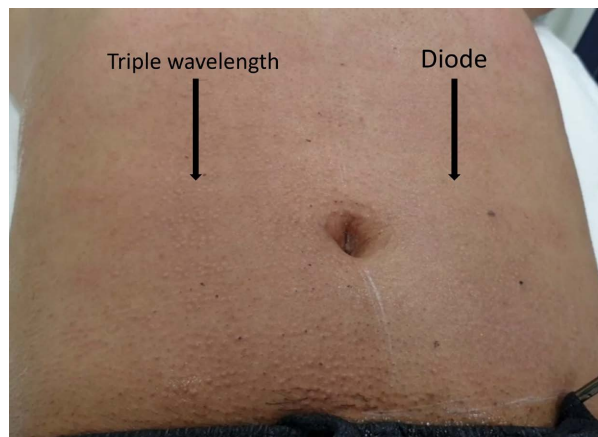


Figure 1. Immediate effects: perifollicular erythema and edema with triple-wavelength and 810 nm diode lasers.

Table 1. Quantitative analysis of hair reduction and GAIS.

Patient	Treated area	Investigator 1			Investigator 2			Investigator 1			Investigator 2		
		Hair reduction (%)		Triple Wav. vs 810 nm	Hair reduction (%)		Triple Wav. vs 810 nm	GAIS scale		Triple Wav. vs 810 nm	GAIS scale		Triple Wav. vs 810 nm
Triple Wav.	810 nm	Triple Wav.	810 nm		Triple Wav.	810 nm		Triple Wav.	810 nm		Triple Wav.	810 nm	
1	Abdomen	68%	43%	59%	58%	39%	49%	4	3	33%	4	3	33%
2	Back	93%	80%	17%	87%	73%	18%	5	4	25%	5	4	25%
3	Arms	85%	78%	10%	89%	81%	10%	5	4	25%	5	5	0%

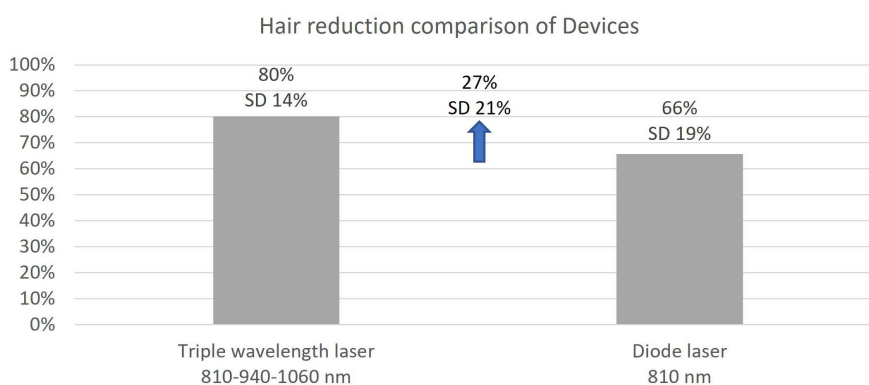


Figure 2. Hair reduction: comparison of devices.

The GAIS assessment was between 4 and 5 for the triple-wavelength diode laser, and between 3 and 5 for the 810 nm diode laser, which represented an improvement of 0% - 33% for the side treated with the triple wavelength. On average, the triple-wavelength diode laser had a GAIS scale result of 4.67 out of 5 (SD 0.52), while the 810 nm diode laser obtained a value of 3.83 out of 5 (SD 0.75). By way of comparison, an improvement of 24% (SD 12%; $p = 0.0041$) on the GAIS scale was obtained using the triple-wavelength diode laser.

Figure 3 and **Figure 4** show before and after pictures of the subjects treated in the abdominal and back areas. A greater reduction was observed on the right side treated with the triple-wavelength diode laser, even 2 years after the last session (**Figure 3(c)**).

The results obtained have been compared with thermal simulations (**Figure 5** and **Table 2**). The simulations showed a greater heating of the hair and less heating of the skin with the triple-wavelength applicator. From the thermal damage results, it can be deduced that the triple-wavelength diode laser produced 29% higher thermal damage than the 810 nm diode laser, showing good concordance with the clinical results.

4. Discussion

This comparative case study aimed to compare the efficacy and safety between the triple-wavelength (810, 940 and 1060 nm) diode laser and the 810 nm diode laser.

One of the most widely used techniques for the elimination of unwanted hair is the 810 nm diode laser, which has established itself as an effective and safe technique [4] [5] [6]. However, on dark skin types, safety problems could arise from the light absorption by the melanin of the skin. The triple-wavelength diode laser, made up of the combination of 810 nm, 940 nm and 1060 nm wavelengths, has allowed safe treatments to be performed with a much higher fluence than the single 810 nm wavelength, due to the use of longer wavelengths which are absorbed less by the skin. Other combinations of triple wavelengths that are available (for example: 755 nm, 810 nm and 1060 nm) could be considered less effective and less safe. This is because the melanin of the skin absorbs the lower



Figure 3. Abdomen. Right side treated with the triple-wavelength (Blend) applicator and left side with the 810 nm applicator. Before treatment (a), after 3 treatment sessions (b), and 2 years after the last session (c).

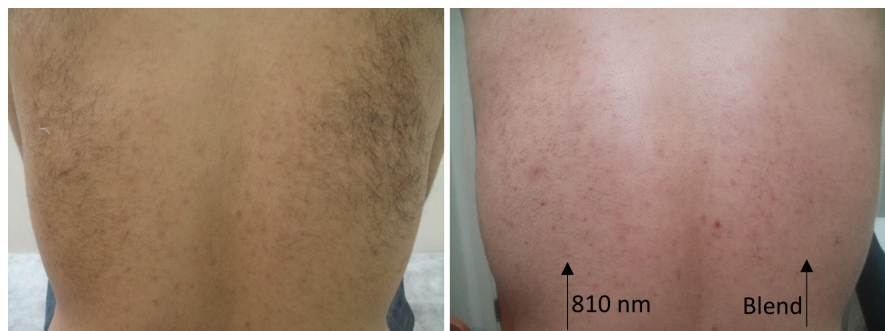


Figure 4. Subject treated on the back. Right side treated with the triple-wavelength (Blend) applicator and the left side with the 810 nm applicator. Left image is before the first treatment; right image is after 4 sessions.

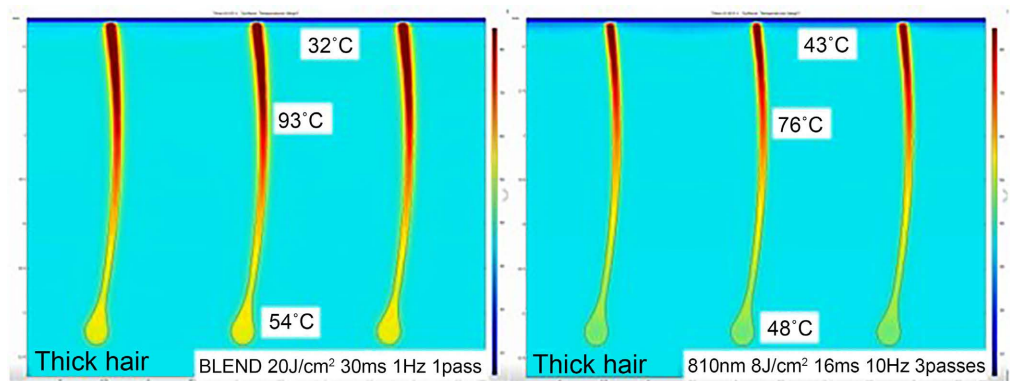


Figure 5. Simulation of hair heating for skin type IV and dark thick hair with triple wavelength (Blend) applicator (left), and 810 nm applicator (right).

Table 2. Simulation results for dark thick hair on skin type IV using the 810 nm diode laser in dynamic mode and the triple-wavelength diode laser in static mode.

RESULTS OF SIMULATIONS		Diode laser parameters			Shaft			Bulb		Hair follicle Average hair damage	Triple Wav. vs 810 nm
		Fluence	Pulse duration	Freq.	Epidermis	Hair	Stem cells	Hair	Growing cells		
Type of hair	Device	J/cm ²	ms	Hz	T (°C)	T (°C)	T (°C)	T (°C)	T (°C)	q	(qblend-q810): 0.63
Dark Thick	Triple Wav. Static	20	30	1	28	93	58	54	42	0.31	29%
Dark Thick	810 nm Dynamic	8	16	10	36	76	53	48	40	0.13	

wavelength more (755 nm), making it necessary to reduce the fluence parameters and therefore the efficacy of the laser in order to maintain the safety of the treatment.

According to the results of the thermal simulations, a higher fluence could still be used with the triple-wavelength diode laser, given that the simulated temperature of the skin was 32°C (Figure 5). To reach the same epidermal temperature of 43°C obtained with the 810 nm diode laser, the thermal simulations suggest that a fluence of 38 J/cm² should be used (Figure 6). This fluence is indeed within the range of fluences used on skin type I according to the protocols for the 810 nm diode laser, which suggests that patients with dark skin types could also achieve hair reduction results similar to those obtained in subjects with lighter skin types. However, clinical studies with larger groups of subjects would be necessary to confirm this hypothesis, and great care would have to be taken with regard to adverse effects.

There are several factors that can explain the higher efficacy obtained with the triple-wavelength diode laser. Firstly, the ability to apply higher fluences using stamping mode, which allows more energy to heat the hair. Secondly, longer wavelengths are less prone to scattering in the dermis and thus penetrate further into the dermis and allow deeper and more uniform heating of the hair. Thirdly, the 940 nm and 1060 nm wavelengths also show significant absorption by blood and water, which, combined with absorption by the melanin of the hair, can produce greater heating of the hair follicle. All these factors have been considered in the skin and hair model used in the thermal simulations [16].

These results are consistent with those presented in the studies by Fajardo *et al.* [13] and Gold *et al.* [15] where the Primelase device with the triple-wavelength diode laser showed greater reduction than the 810 nm diode laser by 55% and 12%, respectively.

The fact that the triple wavelength is more efficient on darker skin types implies a great advantage for South Asian patients since dark skin types are difficult to treat with most of the diode lasers on the market and the procedure is often painful and less effective.

The subjects in this study achieved a mild to moderate end point, which disappeared less than 48 hours after treatment. A higher end point was observed in



Figure 6. Simulation of hair heating for skin type IV and dark thick hair in maximum operating conditions with a triple wavelength (Blend) laser of 810 + 940 + 1060 nm.

procedures using the triple-wavelength applicator, in good concordance with the greater temperature in the hair follicle. No adverse side effects were observed in any case, so it can be inferred that the use of triple wavelength laser is safe and effective for hair removal treatments on dark skin.

5. Conclusions

On darker skin types, the triple-wavelength diode laser (810 nm, 940 nm, 1060 nm) has been found to be more effective for permanent hair reduction compared to the 810 nm diode laser. The triple-wavelength laser has been found to cause less absorption by the skin, enabling the use of higher fluences with greater safety, which allows it to be used in stamping mode at a high fluence. In addition, longer wavelengths have a greater penetration which allows the hair to be treated at a deeper level.

In future research, a larger sample of subjects should be considered to obtain more representative results and should include participants with light and dark skin types to evaluate the efficacy and safety of the triple-wavelength diode laser on all skin types.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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