International Research Journal of Pharmacy and Medical Sciences
ISSN (Online): 2581-3277

Efficacy of Thin Hair Removal by Dynamic Application of 810-nm Diode Lasers: *In Silico* and Clinical Comparative Study of Two Laser Powers: 4,800W and 1,000W

Mariano Velez González[1], Gregorio Viera Mármol[2]
[1]Centro Medico Ronefor. Barcelona, Spain
[2]Departamento Científico de Cocoon Medical, Barcelona, Spain

***Abstract*— Background**: *Photoepilation of thin hair still represents a challenge for aesthetic medicine. Current commercially available photoepilation devices present limitations for thin hair removal, where efficacy mainly depends on parameters like pulse duration and applied fluence.* **Objective**: *This study aims to verify the hypothesis that a dynamic mode (multiple passes with a low fluence and high repetition rate) using a short pulse duration provides better results than longer pulse durations, while still being safe and comfortable.* **Materials and methods**: *In order to define the best parameters for the laser set-up, we hereby provide an in silico study as well as a prospective clinical comparison of the efficacy of thin hair removal using the dynamic mode. Short laser pulses with a high laser power (3 ms with the 4,800W, 810-nm Primelase device) as well as longer pulses with a moderate power (11/14 ms with the Primelase device adjusted to 1,000W), reaching identical fluence doses, have been applied in three sessions in a side-by-side study with fourteen subjects on different parts of the body. The efficacy, side effects, and degree of satisfaction of the subject and investigator were assessed.* **Results**: *The results predicted by the simulation were corroborated by the clinical data. Using the shortest pulse duration, simulations revealed an average improvement of 15% with original-size hair, and a significantly greater improvement of 21% with the residual thinned hair. Hair counts performed three months after the third treatment showed an overall main hair reduction of 64% on the side treated with the pulse duration of 3 ms, and 55% on the side treated with longer pulses of 10 ms and 14 ms (which represents a 16% greater efficacy with 3ms, with a p-value of <0.024), with a maximum difference of 73% and 46% respectively (59% improvement) in the upper leg where the hair is thinner. The investigator rated 64% of the areas treated with 3 ms as producing good results, compared to only 36% of the areas treated with 10 and 14 ms (p<0.019). In addition, only mild and temporal side effects were reported, without remarkable differences between both sides.* **Conclusions**: *This clinical study corroborates the results of the simulations which predicted that the dynamic mode of the 4,800W diode laser device would be more effective than other systems with less power, while also being comfortable and safe. Nevertheless, more subjects as well as more sessions and an evaluation of long-term results would be needed to validate the simulations that predict even better results for the residual thinned hair.*

***Keywords*—** *Residual thin hair, 810-nm diode laser, Dynamic mode, Short and long pulse, Hair removal, Primelase.*

I. Introduction

Photoepilation (epilating with light) is one of the most widely used hair removal techniques worldwide. As a highly effective treatment, it has replaced the majority of other hair removal systems in the last decade (waxing, tweezing, shaving, sugaring, threading, etc.) (1-6).

The effect of photoepilation with laser light is based on a process of selective photothermolysis produced by laser impulses that selectively heat the hair (7). Among the different systems, solid state lasers like Alexandrite, Nd: YAG and diode lasers of different wavelengths have already demonstrated effectiveness and safety (1-4).

One of the challenges with this type of application is the treatment of residual hair or very thin hair, since not all systems offer satisfactory efficacy on thinned hair. Laser pulse duration, together with the dose of applied fluence, are the most important parameters that influence effective epilation of thin hair. However, there are very few studies in which an assessment of the impact of these parameters on the efficacy for thin hair has been studied (8-10). Besides, said studies were only performed using a traditional static laser pulse mode (low frequency, single shots), because the dynamic laser pulse mode (high frequency, multiple shots) has just recently joined the battery of hair removal procedures (5-6, 11). The use of a dynamic mode allows various passes to be applied to the treated area. This way, the applied fluence is lower, the frequency is higher and, most importantly, patient comfort is substantially increased.

To the best of our knowledge, we are hereby comparing, for the first time, the efficacy of short-duration (3 ms) dynamic laser pulses produced by a 4,800W laser to longer pulses (10/14 ms) produced by a 1,000W laser. First, we predicted the efficacy of photoepilation as a function of hair thickness with our 3D mathematical simulation model, previously developed in our laboratory (12). Then, the increased efficacy on thin hair when using dynamic mode and short laser pulses (4,800W laser) was proved experimentally. The approach of using dynamic mode with a short pulse duration represents a paradigm shift for the treatment of thin hair.

II. Material and Methods

A. In Silico Study

3D *in silico* COMSOL Multiphysics® mathematical model of hair and skin heating has been used to predict hair removal

Mariano Velez González and Gregorio Viera Mármol, "Efficacy of Thin Hair Removal by Dynamic Application of 810-nm Diode Lasers: *In Silico* and Clinical Comparative Study of Two Laser Powers: 4,800W and 1,000W," *International Research Journal of Pharmacy and Medical Sciences (IRJPMS)*, Volume 4, Issue 1, pp. 15-23, 2020.

efficacy (12). In summary, the 3D model includes sapphire contact cooling along with epidermis, dermis, and hair follicle structure. The hair model was divided into three zones: upper shaft, lower shaft and bulb. Furthermore, 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 100 µm from the surface of the shaft to account for the stem cells located in the bulge. The geometric model used in the numerical simulation was separated 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 and, in particular, to determine the temperature and thermal damage for the skin and hair types of the subjects included in this study.

Regarding the hair model, different dimensions were considered in the simulations: untreated or original-size hair, and the so-called "residual" thinned hair. For each simulation, precise laser parameters and the skin and hair characteristics were reproduced. The resulting temperatures and levels of thermal damage to the hair follicle have been used to compare the 4,800W (3 ms pulse) and 1,000W (10/14 ms pulse) devices.

B. Open Label Side-By-Side Prospective Clinical Study

The study was conducted in compliance with the principles set forth in the current version of the Declaration of Helsinki, Good Clinical Practice, and the laws and regulatory requirements for the use of medical devices in Spain. All subjects were consulted, gave consent and clearly understood the procedure prior to the study. All procedures fulfilled Organic Law 15/1999 on the Protection of Personal Data and Regulation (EU) 2016/679 of the European Parliament and the Council of April 27, 2016 concerning the protection of natural persons with regard to the processing of personal data and the free circulation of said data.

This was a prospective, single-center, side-by-side clinical study. The efficacy, safety and comfort of dynamic-mode laser hair removal performed on thin hair growing on the arms, legs and buttocks were evaluated by comparing two pulse durations: 3 ms and 10/14 ms. 14 female subjects with skin types between II and III, thin hair, brown and black hair, and aged between 18 and 50 years were recruited for the study. Importantly, the subjects did not undergo any prior hair removal treatments (i.e. waxing) during the previous month and were not subject to any hormonal treatments. The patients were treated three times at intervals of 2 months, and the efficacy was assessed 3 months after the third treatment.

All patients who did not meet the inclusion criteria were excluded from the study. In addition, subjects with an allergy to visible and infrared light or treatments with visible and infrared photosensitive drugs, subjects with white or very blonde hair, and subjects with any infection sensitivity issues or with an oncologic process in the treatment area were excluded.

C. Laser Device

A Primelase Excellence diode laser device (from Cocoon Medical, Barcelona, Spain) was used for the clinical study. The applicator head used was 4,800W, 810 nm and 20x9 mm^2. Two different pulse durations were compared: the minimum pulse corresponding to the maximum peak power (which was 3 ms for all treatments) was applied on the left side, and long pulses (10/14 ms) with a reduced power of 1,000W were applied on the right side. Identical fluence doses were applied across 3 hair removal sessions. The Primelase devices operated in dynamic mode at 10Hz.

Before carrying out the hair removal sessions, the areas to be treated were shaved and a thin layer of transparent Aqualaser gel (Ultragel) was applied. The diode laser head was placed in contact with the skin while exerting slight pressure. The device emitted laser energy through a cold sapphire crystal window that was also used to cool the skin via continuous-contact cooling. The treatment was performed in dynamic mode by moving the head of the device horizontally or vertically in a sweeping motion until the target total accumulated energy was reached. A constant speed was maintained to ensure an even sweep of the entire grid (treated area). The approximate average speed of movement across each grid was 10 cm/s. The exact parameters were chosen by a board-certified dermatologist in accordance with the skin and hair type of each treated subject (Table I). After each treatment session, aloe vera gel was used for post-treatment massage.

TABLE I. Dynamic-mode treatment parameters for the 810-nm, 20x9 Primelase device

Skin type (Fitzpatrick scale)	Grid (cm x cm)	Pulse duration (ms)	Fluence (J/cm^2)	Accumulated energy (kJ)	Frequency (Hz)
Short pulse (up to 4,800W) applied on left side					
II	10x10	3	8	3.5	10
III	10x10	3	6	3	10
Long pulse (1,000W) applied on right side					
II	10x10	14	8	3.5	10
III	10x10	10	6	3	10

D. Evaluation of the Efficacy, Safety and Patient Comfort during the Treatment

End-point and patient comfort were evaluated during the treatment and immediately afterwards, both visually and with before and after images using a Lumix camera (Panasonic DMC-LX100). To evaluate pain during the treatment, subjects were asked to rate it from 0 to 10 (0 being no pain and 10 being unbearable pain) on a Visual Analogue Scale (VAS) and to indicate the type of pain experienced (puncture, heat or both). Subjects were asked if there was a need to apply cold. Immediate side effects, such as the presence of erythema, edema, itching, hematoma, pigmentation disorders and burns, were also evaluated. Edema, erythema and itching were rated from 0 to 10.

The efficacy was compared using semi-quantitative scales, hair counts and mathematical 3D simulations. Images were taken before each session and three months after the third

Mariano Velez González and Gregorio Viera Mármol, "Efficacy of Thin Hair Removal by Dynamic Application of 810-nm Diode Lasers: *In Silico* and Clinical Comparative Study of Two Laser Powers: 4,800W and 1,000W," *International Research Journal of Pharmacy and Medical Sciences (IRJPMS)*, Volume 4, Issue 1, pp. 15-23, 2020.

session. Hair counts across 16 cm^2 (4x4 cm template) using a Microsoft image with SAKE filter for greater contrast were applied. For the semi-quantitative assessment, the investigator visually assessed the hair reduction and ranked the results: 4 = very good efficacy with 90-100% hair reduction, 3 = good efficacy with 61-89%, 2 = moderate efficacy with 31-60%, 1= low efficacy with 1-31%, and 0 = no effect.

E. Statistical Analysis

A paired student's t-test was performed as the data showed a normal distribution. Mean value, standard error (SE), ranges and percentages for the categorical variables were used to evaluate all data. The improvement between 4,800W and 1,000W devices was calculated from the difference between both devices divided by the result with 1,000W. Microsoft Excel was used for the statistical analysis. Statistical significance was considered to be $p<0.05$.

III. RESULTS

A. In Silico 3D Simulation

We predicted the efficacy for 1,000W and 4,800W using a 3D in silico model (12). The temperature and thermal damage to the hair follicle were simulated for each of the hair removal treatments in this study. When using the maximum laser power, an overall improvement in temperature and thermal damage was observed when compared with the reduced power of 1,000W, both in terms of the original-size and the residual thinned hair (Table II and Figure 1). The pulse duration was 10.9 ms on average for 1,000W, and 3 ms for the maximum power of up to 4,800W. The improvement in efficacy has been calculated from the difference between the thermal damage results divided by 0.63, which is the value at which the damage becomes irreversible (12). Accordingly, the simulations showed higher efficacy with the treatments performed at the maximum power. More improvement (21%) was obtained for the residual thinned hair and 15% improvement was obtained for the original-size hair.

B. Clinical Study

The promising modeling results were then compared with a side-by-side clinical study. A total of 14 subjects (skin type II – 4 subjects, skin type III – 10 subjects) aged between 18 and 49 were included in the clinical study. Laser hair removal on the arms was performed in dynamic mode on 7 subjects, on the legs on 6 subjects, and on the buttocks on 1 subject (Table III).

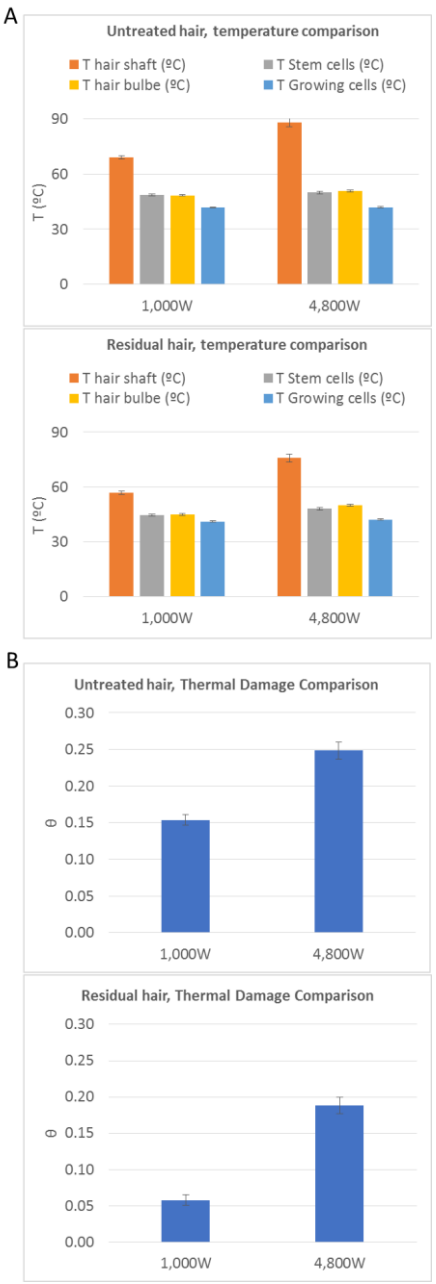

Fig. 1. Weighted average differences in temperatures of the hair shaft, stem cells, hair bulb and growing cells (A), and thermal damage (B) according to the in silico study on untreated and residual hair, comparing 1,000W (10/14 ms) and 4,800W (3 ms).

TABLE II. Overall average simulation results for original-size (untreated) and thinned hair (residual) using 1,000W and the maximum power of up to 4,800W.

RESULTS OF SIMULATIONS, mean values & SE		Diode Laser parameters					Shaft				Bulbe				Hair follicle Average hair damage		Improvement 4800W vs 1000W
		Fluence		Pulse duration		Freq.	Hair		Stem cells		Hair		Growing cells				
Type of hair	Device	J/cm2)	Error	ms	Error	Hz	T (ºC)	Error	T (ºC)	Error	T (ºC)	Error	T (ºC)	Error	θ	Error	$(\theta_{4800}-\theta_{1000})$:0,63
un-treated	1000W	6.46	0.27	10.92	0.55	10.00	69.09	1.00	48.72	0.54	48.27	0.41	41.64	0.24	0.15	0.01	
residual							56.76	0.62	44.44	0.33	44.96	0.20	41.10	0.19	0.06	0.01	
un-treated	4800W	6.46	0.27	3.00	0.00	10.00	88.07	2.24	49.92	0.65	50.63	0.60	41.87	0.26	0.25	0.01	15%
residual							75.81	1.71	48.04	0.56	50.08	0.58	42.19	0.28	0.19	0.01	21%

Mariano Velez González and Gregorio Viera Mármol, "Efficacy of Thin Hair Removal by Dynamic Application of 810-nm Diode Lasers: *In Silico* and Clinical Comparative Study of Two Laser Powers: 4,800W and 1,000W," *International Research Journal of Pharmacy and Medical Sciences (IRJPMS)*, Volume 4, Issue 1, pp. 15-23, 2020.

TABLE III. Characteristics of the subjects involved in the study.

Nº	Hair type	Hair color	Age	Treated area
1	III	Brown	36	Arms
2	III	Brown	29	Arms
3	III	Brown	29	Legs, upper front
4	III	Brown	29	Legs, upper back
5	III	Black	18	Arms
6	III	Black	18	Legs, upper front
7	III	Black	18	Legs, upper front
8	III	Brown	25	Arms
9	II	Brown	22	Arms
10	II	Brown	22	Legs, upper front
11	II	Brown	22	Legs, upper back
12	III	Brown	29	Buttocks
13	III	Black	28	Arms
14	II	Brown	49	Arms

The left side was treated with the maximum power of up to 4,800W (3 ms) and the right side was treated with 1,000W (10/14 ms). Hair counts revealed an overall hair reduction of 64% (SE 5%) with 4,800W and 55% (SE 5%) with 1,000W, which corresponds to a statistically significant improvement of 16% (p-value of <0.024). The maximum improvement on the side treated with 4,800W was 77%. Comparative results for each subject are reported as a supplemental table (Table S1). Examples of hair removal are illustrated in figure 2.

Analysis with respect to the treated area revealed different improvements in hair reduction results (Table IV). The area on the back of the upper leg showed the largest difference (59%), achieving a hair reduction of 73% with 4,800W. The arm and buttock areas presented a smaller difference, 11% and 14% respectively, with a hair reduction of 62% and 64% respectively with 4,800W.

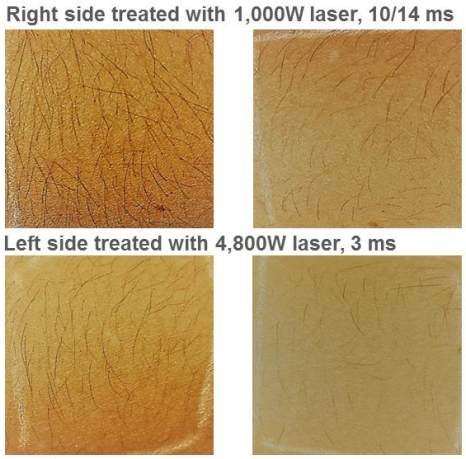

Fig. 2. Example of hair removal results: subject 8 with skin type III and brown hair treated on the arms; the hair count shows an improvement of 18% when using 4,800W.

The hair removal results were also evaluated according to a semi-quantitative assessment (Figure 3). For the side treated with 4,800W (3 ms), the hair reduction achieved was considered a good result in 9 of 14 subjects (64%), compared to only 36% (5 of 14 subjects) in those treated with 1,000W (10/14 ms). Similarly, a lower number of mild results, 7% (1 of 14 subjects), was reported with 4,800W, while up to 14% (2 of 14 patients) was reported with 1,000W. At 1,000W, the majority of results (9 of 14, 64%) were considered as moderate or mild. An average score of 2.6 was obtained for 4,800W compared to 2.2 for 1,000W (4 being very good and 0 being no effect), which was statistically significant with a p-value of < 0.019.

TABLE IV. Comparative hair count results with respect to the treated area.

Type of area treated	Device	Before T1 (#)	Post T3 (#)	% reduction	4,800W vs 1,000W Improvement (%)
Arm	Right side 1,000W	123.57	54.14	56%	11%
	Left side 4,800W	118.42	45.28	62%	
Front of the upper leg	Right side 1,000W	75.66	25.66	66%	15%
	Left side 4,800W	82	19.33	76%	
Back of the upper leg	Right side 1,000W	82	44.33	46%	59%
	Left side 4,800W	111	29.66	73%	
Buttock	Right side 1,000W	167	73	56%	14%
	Left side 4,800W	135	49	64%	

Investigator assessment	Device	Number of cases	%	Arm	Front of the upper leg	Back of the upper leg	Buttock
Very good (91-100%)	Right side 1,000W	0	0%	0	0	0	0
	Left side 4,800W	0	0%	0	0	0	0
Good (61-90%)	Right side 1,000W	5	36%	2	2	1	0
	Left side 4,800W	9	64%	5	2	2	0
Moderate (31-60%)	Right side 1,000W	7	50%	5	1	1	0
	Left side 4,800W	4	29%	1	1	1	1
Mild (0-30%)	Right side 1,000W	2	14%	0	0	1	1
	Left side 4,800W	1	7%	1	0	0	0

Fig. 3. Comparative investigator assessment using semi-quantitative scales.

Since patient safety and comfort is of the utmost importance, side effects and assessments of pain, heat sensation, itching and its duration, as well as erythema and peripheral edema, were methodically evaluated during and after each treatment (Table S2). Reported side effects were generally mild. Subjects reported only mild pain with an average of 3 for both laser powers (SE 0.5 with 1,000W and 0.65 with 4,800W), with a maximum of 6 for 1,000W and 8

Mariano Velez González and Gregorio Viera Mármol, "Efficacy of Thin Hair Removal by Dynamic Application of 810-nm Diode Lasers: *In Silico* and Clinical Comparative Study of Two Laser Powers: 4,800W and 1,000W," *International Research Journal of Pharmacy and Medical Sciences (IRJPMS)*, Volume 4, Issue 1, pp. 15-23, 2020.

for 4,800W. In addition, a moderate heat sensation with an average of 4 for both powers (SE 0.5 with 1,000W and 0.53 with 4,800W), and a maximum of 7 in both cases was noted. The sensation of itching or pruritus was also mild, with an average of 3 for both powers (SE 0.45 with 1,000W and 0.46 with 4,800W), and a maximum of 6 in both cases. Regarding the duration, it was very short on average, at 2 minutes on the side treated with 1,000W (SE 0.64) and 3 minutes on the side treated with 4,800W (SE 0.67). In both cases, the sensation lasted up to 10 minutes and in one instance it coincided with a dermographism effect. The detected peripheral erythema was also mild, at an average of 2 in both cases (SE 0.37 with 1,000W and 0.43 with 4,800W), with a maximum of 6 on the right side (long pulse, 1,000W) and 1.92 on the left side (short pulse, 4,800W), and ranging from a minimum of 0 to a maximum of 6 (in an instance that coincided with dermographism). Similarly, the peripheral edema was mild, at an average of 2 for both cases (SE 0.25 with 1,000W and 0.43 with 4,800W), with a maximum of 4 for 1,000W and 6 for 4,800W. In conclusion, there were almost no side effect differences between using a short or long dynamic pulse duration. Regarding complications or adverse effects (burns, blisters, crusting, ulcer infection, and possible hypo- or hyperpigmentation), they were not observed in any of the subjects.

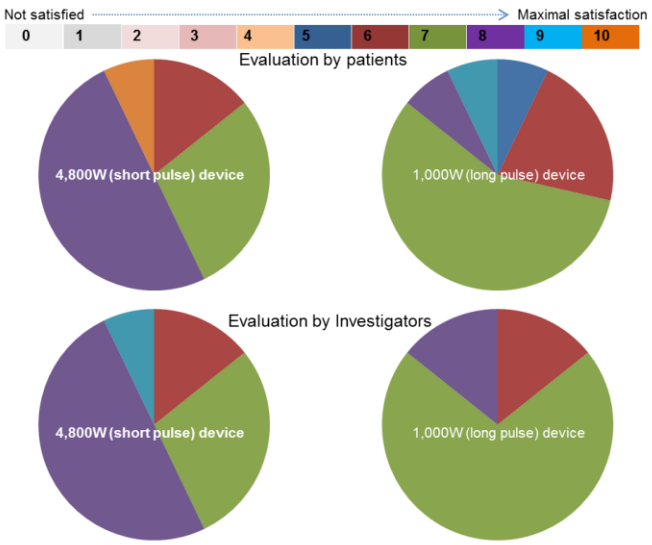

Fig. 4. Graphical results of the satisfaction survey completed by the patients and investigators. 10 is maximum satisfaction and 0 is not satisfied.

Finally, the subjective degree of satisfaction evaluations provided by the patient and the investigator (in which 10 is the maximum satisfaction and 0 is not satisfied) were carried out three months after the last treatment (Figure 4, Table S3). Patients were significantly more satisfied with depilation using the 4,800W device ($p<0.0028$). On average, patients gave a score of 7 (SE 0.25) to the right side treated with 1,000W (between 5 and 9) and 8 (SE 0.27) to the left side treated with 4,800W (between 6 and 11). Similarly, regarding the degree of satisfaction of the investigator, an average score of 7 (SE 0.15) on the right side treated with 1,000W (between 6 and 8) and 8 (SE 0.23) on the left side treated with 4,800W (between 6 and 9) was reported, which was statistically very significant ($p<0.0032$) (Figure 4, Table S3).

IV. Discussion

The objective of this study was to evaluate the differences in efficacy, side effects and overall patient comfort for laser hair removal in dynamic mode with a high-power diode laser device of 4,800W and a moderate-power diode laser of 1,000W. These types of studies are important to offering the best possible treatments. However, to the best of our knowledge, this is the first time a study of this kind has been performed. There are no other studies that have assessed the dynamic application of the photoepilation technique using different laser powers, and hence different laser pulse durations, with special attention paid to the removal of thin hair.

We have shown that the best results are obtained with shorter pulse durations and, therefore, with higher laser power, since higher temperature is generated in the hair follicle and therefore greater thermal damage. The *in silico* model used in this study has predicted a significant improvement in efficacy when using the 4,800W device parameters that can provide a short laser pulse of up to 3 ms, compared to a 1,000W device that requires a longer pulse duration above 10 ms to reach the same fluence. This result has been corroborated by a clinical study. A statistically significant improvement in efficacy of 16% has been obtained after just 3 sessions of dynamic-mode hair removal, which is expected to increase to 21% with the residual thinned hair remaining from the previous sessions, according to the simulations. The thermal relaxation time (TRT) of the hair is the key to understanding the results of this study (12). In the case of original or untreated hair, the TRT is between 20 ms and 50 ms. Therefore, moderate-power lasers that operate with 20 ms pulses, for example, can effectively heat this type of hair. However, residual thinned hair exhibits a TRT of less than 10 ms. In these cases, high-power lasers in dynamic mode producing pulses of less than 10 ms allow this hair to be heated with a high level of efficacy and enable the high values of thermal damage required for permanent hair removal to be achieved. However, pulses longer than the TRT (longer than 10 ms) will result in limited heating of the target.

Previous studies with Alexandrite lasers on thin hair (8) also recommend short pulses. Accordingly, effective thin facial hair removal was only observed after a high number of sessions. In another study with IPL (9), which evaluated the effectiveness on thin hair in non-facial areas using short pulses (3-5 ms), 25% of the results obtained were good and 25% were moderate. In comparison, the results observed in our study have been superior (64% good results, 29% moderate results), although the outcomes were evaluated just 3 months post-treatment.

Interestingly, it has been observed that the relative increase in efficacy was superior (27%) on the back of the legs when compared to the arms and the front of the legs, and this was even more significant with respect to the buttocks. As mentioned above, this is probably due to the presence of thinner hair with a lower TRT on this part of the legs, and the

Mariano Velez González and Gregorio Viera Mármol, "Efficacy of Thin Hair Removal by Dynamic Application of 810-nm Diode Lasers: *In Silico* and Clinical Comparative Study of Two Laser Powers: 4,800W and 1,000W," *International Research Journal of Pharmacy and Medical Sciences (IRJPMS)*, Volume 4, Issue 1, pp. 15-23, 2020.

fact that the 4,800W device is capable of heating thinner hair with greater efficacy thanks to its short pulse duration, which is shorter than the TRT.

Altogether, a high hair reduction has been obtained (64%), especially considering that this study has been carried out with only three sessions and a 3-month assessment. It is worth noting that, on average, 6 to 8 sessions are recommended to obtain a reduction of 70 to 90% for moderate and thick hair in bodily areas. The greater efficacy of the Primelase equipment on residual hair suggests that the number of sessions needed to achieve permanent hair removal will be smaller.

Importantly, no complications were observed and side effects were either transient, mild or, in some cases, moderate. This shows that the application of the dynamic mode with short laser pulses of up to 3 ms allows comfortable and safe dynamic-mode hair removal treatments to be performed.

The subjects reported a high degree of satisfaction (8 on a scale of 0-10) using a short-pulse laser (4,800 W), which coincided with the investigator's assessment. For the area treated with a long-pulse laser (1,000W), the satisfaction was lower (7 on a scale of 0-10), which was reported by both patients and investigators.

Thus, the results obtained are very satisfactory, although we would recommend performing more sessions with a longer interval for post-treatment assessment. We believe that the two-month treatment interval used in this study is the most recommended, at least for non-facial areas (5, 6). Other authors (8, 13) have reported one month in subjects undergoing facial treatments.

Simulations have become a very useful tool for calculating the effect of new treatments on skin and hair. The fact that the clinical results match the results of the simulations further validates our simulation model and provides a very powerful tool for assessing the effectiveness of future treatments.

V. CONCLUSIONS

The dynamic mode of the 4,800W device, which operates with pulses of up to 3 ms, has been shown to lead to statistically significant improvement in hair removal results, as shown in both *in silico* and clinical studies. The clinical study has shown an average hair reduction of 64% in just 3 sessions and a significant improvement of 16% compared with a 1,000W system ($p<0.024$). The *in silico* study has predicted a larger improvement of 21% for residual hair, thanks to the shorter pulses of the 4,800W device which effectively damage the thinned hair follicles. Additionally, pain and side effects remained mild and did not increase over the shorter pulses. Accordingly, fewer sessions are needed to achieve total hair removal with a high-power diode laser of 4,800 W.

Therefore, the high laser power of the 4,800W primelase device allows for more effective hair removal in dynamic mode, especially for thin hair, while maintaining the comfort and safety that characterize this new hair removal mode.

It would be important to increase the number of subjects, carry out more treatment sessions, and have a longer post-treatment assessment period (greater than 6 months) to gather more objective data regarding long-term efficacy.

REFERENCES

[1] Dorgham NA, Dorgham DA. Lasers for Reduction of Unwanted Hair in Skin of Color: A Systematic Review and Meta-analysis. J Eur Acad Dermatol Venereol. 2019 Oct 6.
[2] Aleem S, Majid I. Unconventional Uses of Laser Hair Removal: A Review. J Cutan Aesthet Surg. 2019;12:8-16.
[3] Gan SD, Graber EM. Laser hair removal: a review. Dermatol Surg. 2013 Jun;39(6):823-838.
[4] Drosner M, Adatto M. Photo-epilation: guidelines for care from the European Society for Laser Dermatology (ESLD). J Cosmet Laser Ther. 2005;7:33-38.
[5] Velez-González M, Cisneros-Vela JL. Fundamentos de la Fotodepilación. En Cisneros JL, Camacho FM, Trelles MA editores. Lasers en Dermatología y Dermocosmética. Aula Medica, Madrid. 2008:275-296.
[6] Fajardo Urdiales C, Martin Escobedo AB, Vélez González M. Hirsutismo. En Protocolo de Práctica Clínica en Medicina Estetica. Revista SEMA. Febrero 2016:105-124.
[7] Altshuler GB, Anderson RR, Manstein D, Zenzie HH, Smirnov MZ. Extended Theory of Selective Photothermolysis. Lasers in Surgery and Medicine. 2001;29:416-432.
[8] Uyar B, Saklamaz A. Effects of the 755-nm Alexandrite laser on fine dark facial hair: review of 90 cases. J Dermatol. 2012;39:430-2.
[9] Holzer G, Nahavandi H, Neumann R, Knobler R. Photoepilation with variable pulsed light in non-facial body areas: evaluation of efficacy and safety. 2010;24(5):518-23.
[10] Fajardo-Urdiales C, Rodríguez-Casimiro AB, Villena J, Pérez MLl, Vicente Solà JS, Viera-Mármol G. Comparative Clinical Study and Thermal Modelling of Photoepilation of Thin Hair by Primelase Excellence 810nm and Blend and Soprano XL 810nm. International Research Journal of Pharmacy and Medical Sciences. 2019;3(1):15-24.
[11] Pai GS, Bhat PS, Mallya H, Gold M. Safety and efficacy of low-fluence, high-repetition rate versus high-fluence, low-repetition rate 810-nm diode laser for permanent hair removal – a split-face comparison study. J Cosmet Laser Ther. 2011;13:134-137.
[12] Viera Mármol G, Villena J, New 3D in silico model of hair and skin heating during laser hair removal. International Research Journal of Pharmacy and Medical Sciences (IRJPMS). 2019;3:15-24
[13] Willey A, Torrontegui J, Azpiazu J, Landa N. Hair stimulation following laser and intense pulsed light photo-epilation: review of 543 cases and ways to manage it. Lasers Surg Med 2007;39:297-301.

TABLE S1. Comparative results and statistics of hair count for each subject between the right side treated with 1,000W and the left side treated with 4,800W.

Nº	Device	Baseline	3 months after T3	% reduction	4,800 vs 1,000 Improvement (%)
1	Right side 1,000W	100	36	64%	16%
	Left side 4,800W	119	31	74%	
2	Right side 1,000W	108	55	49%	-6%
	Left side 4,800W	98	53	46%	
3	Right side 1,000W	34	22	35%	65%
	Left side 4,800W	43	18	58%	
4	Right side 1,000W	84	59	30%	77%
	Left side 4,800W	93	44	53%	
5	Right side 1,000W	123	19	85%	-5%
	Left side 4,800W	137	27	80%	
6	Right side 1,000W	111	35	68%	6%
	Left side 4,800W	92	25	73%	
7	Right side 1,000W	138	38	72%	-16%
	Left side 4,800W	90	35	61%	
8	Right side 1,000W	145	81	44%	41%
	Left side 4,800W	132	50	62%	
9	Right side 1,000W	125	52	58%	23%
	Left side 4,800W	113	32	72%	
10	Right side 1,000W	82	20	76%	14%
	Left side 4,800W	111	15	86%	
11	Right side 1,000W	90	36	60%	48%
	Left side 4,800W	87	10	89%	
12	Right side 1,000W	96	73	24%	37%
	Left side 4,800W	73	49	33%	
13	Right side 1,000W	167	97	42%	-31%
	Left side 4,800W	135	96	29%	
14	Right side 1,000W	97	39	60%	26%
	Left side 4,800W	118	29	75%	

STATISTICS

Average	Right side 1,000W	107	47	55%	16%
Average	Left side 4,800W	103	37	64%	
SD	Right side 1,000W	32.40	23.59	18%	
SD	Left side 4,800W	26.07	21.56	18%	16%
Standard error	Right side 1,000W	8.66	6.30	5%	
Standard error	Left side 4,800W	6.97	5.76	5%	
Maximum	Right side 1,000W	167	97	85%	5%
Maximum	Left side 4,800W	137	96	89%	5%
Minimum	Right side 1,000W	34	19	24%	21%
Minimum	Left side 4,800W	43	10	29%	21%
				p-value	0.024
				Confidence level	**98%**

Mariano Velez González and Gregorio Viera Mármol, "Efficacy of Thin Hair Removal by Dynamic Application of 810-nm Diode Lasers: *In Silico* and Clinical Comparative Study of Two Laser Powers: 4,800W and 1,000W," *International Research Journal of Pharmacy and Medical Sciences (IRJPMS)*, Volume 4, Issue 1, pp. 15-23, 2020.

TABLE S2. Side effect evaluation and statistics for each subject between the right side treated with 1,000W and the left side treated with 4,800W.

N°	Device	Pain (1-10)	Heat (1-10)	Itching post-treat. (1-10)	Itching post-treat. (min)	Erythema (1-10)	Edema (1-10)
1	Right side 1,000W	4	7	1	1	1	2
	Left side 4,800W	3	7	1	1	1	2
2	Right side 1,000W	1	1	1	0	0	0
	Left side 4,800W	1	1	2	2	0	0
3	Right side 1,000W	1	2	1	2	2	2
	Left side 4,800W	2	2	3	5	3	4
4	Right side 1,000W	1	2	2	2	6	4
	Left side 4,800W	1	2	2	2	6	6
5	Right side 1,000W	3	5	5	2	2	2
	Left side 4,800W	3	3	5	10	2	2
6	Right side 1,000W	3	4	4	2	2	2
	Left side 4,800W	3	4	5	2	2	2
7	Right side 1,000W	1	3	3	1	2	2
	Left side 4,800W	1	2	3	1	2	2
8	Right side 1,000W	3	4	2	1	2	2
	Left side 4,800W	1	4	2	3	2	1
9	Right side 1,000W	6	5	3	10	3	2
	Left side 4,800W	7	5	1	1	4	3
10	Right side 1,000W	5	4	4	2	2	1
	Left side 4,800W	7	5	4	1	4	4
11	Right side 1,000W	6	5	6	3	1	1
	Left side 4,800W	8	6	6	4	4	4
12	Right side 1,000W	2	2	1	1	1	1
	Left side 4,800W	3	3	1	1	2	2
13	Right side 1,000W	1	2	1	1	2	1
	Left side 4,800W	1	2	1	1	1	1
14	Right side 1,000W	4	7	1	1	1	1
	Left side 4,800W	3	7	1	1	1	1
STATISTICS							
Average	Right side 1,000W	3	4	3	2	2	2
	Left side 4,800W	3	4	3	3	2	2
SD	Right side 1,000W	1.86	1.89	1.70	2.40	1.38	0.93
	Left side 4,800W	2.44	1.97	1.74	2.50	1.60	1.60
Standard error	Right side 1,000W	0.50	0.50	0.45	0.64	0.37	0.25
	Left side 4,800W	0.65	0.53	0.46	0.67	0.43	0.43
Maximum	Right side 1,000W	6	7	6	10	6	4
	Left side 4,800W	8	7	6	10	6	6
Minimum	Right side 1,000W	1	1	1	0	0	0
	Left side 4,800W	1	1	1	1	0	0
p-value		0.49	1.00	0.55	0.66	0.09	0.04

Mariano Velez González and Gregorio Viera Mármol, "Efficacy of Thin Hair Removal by Dynamic Application of 810-nm Diode Lasers: *In Silico* and Clinical Comparative Study of Two Laser Powers: 4,800W and 1,000W," *International Research Journal of Pharmacy and Medical Sciences (IRJPMS)*, Volume 4, Issue 1, pp. 15-23, 2020.

TABLE S3. Satisfaction survey and statistics for each subject between the right side treated with 1,000W and the left side treated with 4,800W.

Final survey evaluation N°	Device	Subject (1-10)	Investigator (1-10)
1	Right side 1,000W	7	7
	Left side 4,800W	8	8
2	Right side 1,000W	5	7
	Left side 4,800W	6	7
3	Right side 1,000W	8	7
	Left side 4,800W	7	8
4	Right side 1,000W	7	7
	Left side 4,800W	7	8
5	Right side 1,000W	7	7
	Left side 4,800W	8	7
6	Right side 1,000W	9	8
	Left side 4,800W	10	9
7	Right side 1,000W	7	8
	Left side 4,800W	8	8
8	Right side 1,000W	6	7
	Left side 4,800W	8	8
9	Right side 1,000W	6	7
	Left side 4,800W	7	8
10	Right side 1,000W	7	7
	Left side 4,800W	8	8
11	Right side 1,000W	7	7
	Left side 4,800W	8	7
12	Right side 1,000W	6	6
	Left side 4,800W	6	6
13	Right side 1,000W	7	6
	Left side 4,800W	7	6
14	Right side 1,000W	7	7
	Left side 4,800W	8	7
STATISTICS			
Average	Right side 1,000W	7	7
	Left side 4,800W	8	8
SD	Right side 1,000W	0.95	0.55
	Left side 4,800W	1.02	0.85
Standard error	Right side 1,000W	0.25	0.15
	Left side 4,800W	0.27	0.23
Maximum	Right side 1,000W	9	8
	Left side 4,800W	10	9
Minimum	Right side 1,000W	5	6
	Left side 4,800W	6	6
p-value		0.0028	0.003280
Confidence level		99.72%	99.68%

Mariano Velez González and Gregorio Viera Mármol, "Efficacy of Thin Hair Removal by Dynamic Application of 810-nm Diode Lasers: *In Silico* and Clinical Comparative Study of Two Laser Powers: 4,800W and 1,000W," *International Research Journal of Pharmacy and Medical Sciences (IRJPMS)*, Volume 4, Issue 1, pp. 15-23, 2020.