Study of Very Long-Pulsed (100 ms) High-Powered Diode Laser for Hair Reduction on All Skin Types

Eliot F. Battle, Jr., MD and R. Rox Anderson, MD
Wellman Laboratories of Photomedicine, Department of Dermatology
Harvard Medical School, Boston, MA[1]

Provided by Palomar Medical Technologies, Inc.
This manuscript is not a medical literature publication.
Product information is provided solely for user education.

Abstract

An 800 nm diode laser with contact cooling and very long pulse widths provides for effective, long-term hair reduction of medium to coarse pigmented hair, even in some darker-skin subjects. Very long pulse widths allow for all skin types to tolerate substantially higher fluences, and thus darker skin types can be safely and effectively treated. Additionally, preliminary results demonstrate that very long pulse widths do not significantly decrease the efficacy for medium to coarse hair reduction for any given fluence.

Introduction

A clinical study designed to investigate hair reduction (short-term and permanent) using very long-pulsed laser energy on all skin types (Fitzpatrick Skin Types I-VI, Table 1a) was performed at the Wellman Laboratories of Photomedicine, Massachusetts General Hospital.[1] Forty subjects were studied over a one year period. A new classification scale (Table 1b) for skin types is introduced. The Skin Ethnic Color Type (ECT) classifies patients for descriptive purposes based on their skin color and ethnicity. This new classification scale is believed to be significantly more useful in determining appropriate parameters for laser hair removal. Using the existing Fitzpatrick Skin Type scale individuals with, for example, medium brown skin (ECT V), have been variously categorized as Fitzpatrick IV, V or VI (Table 1c). In the remaining parts of this paper patients will be discussed and classified based on the Skin ECT scale and not the Fitzpatrick Skin Type scale.

The effectiveness of laser hair reduction depends on many variables, including the subject's skin type. Laser hair reduction is typically more effective in lighter-skin people with dark hair than in darker-skin people because higher fluences can be safely used.

The challenge associated with laser treatment for darker-skin subjects is to avoid surface skin (epidermal and upper dermal) injury due to absorption of light in the pigmented epidermis, while still causing selective destruction of the underlying pigmented hair follicles.

Treatment (laser epilation) operates on the principle of selective photothermolysis. This process combines selective absorption of light energy by the melanin in hair follicles with suitable fluences (energies per unit area) and pulse durations that are equal to or less than the thermal relaxation time (TRT) of targeted follicles in human skin (10-100 ms). However, additional studies indicate that the ideal pulse duration for medium to coarse hair reduction might be longer than the TRT of the hair follicle. Because the chromophore (melanin in the hair shaft and matrix cells) occupies a much smaller volume compared to the follicle, thermal diffusion is necessary for follicle destruction. Therefore, a much longer pulse duration appears to be required to achieve optimal results. Heat is conducted from the shaft and melanized portion of the bulb to surrounding structures according to the laws of thermal diffusion.

1. Study was funded through a research grant from Palomar Medical Technologies, Burlington, MA

Table 1a: Fitzpatrick Skin Type	
Skin Type	**Description**
I	White, always burns, never tans
II	White, always burns, sometimes tans
III	White, sometimes burns, always tans
IV	White, rarely burns, always tans
V	Brown, moderately pigmented
VI	Black skin

Table 1b: Skin Ethnic Color Types (ECT)	
Skin Type	**Description**
I	Light White plus ethnic origin
II	Medium White plus ethnic origin
III	Dark White plus ethnic origin
IV	Light Brown plus ethnic origin
V	Medium Brown plus ethnic origin
VI	Dark Brown plus ethnic origin

Table 1c: Comparison of Fitzpatrick Skin Type and Ethnic Color Type	
Ethnic Color Type (ECT)	**Fitzpatrick Skin Type**
I	I
II	II
III	III
IV	could be IV, V, VI
V	could be IV, V, VI
VI	could be IV, V, VI

Current laser hair reduction devices have a maximum pulse duration in the 20-40 ms range. Models of skin optics and heat diffusion suggest that the entire hair follicle, including the outer-most follicular structures (where the stem cells are located) can still be selectively damaged when using substantially longer pulse widths than those typically employed. The larger hair follicles (200-300 um) of medium (50-100 um) to thick (>100 um) darkly pigmented hair shafts are theoretically best suited for these longer pulse widths. These longer pulse durations can be safely used with higher fluences when combined with aggressive contact skin cooling which reduces epidermal damage. It is important to note, however, that such cooling must occur not just prior (pre-cooling), but throughout the entire laser pulse, to maximize protection of the epidermis. This type of concurrent (parallel) cooling is effectively implemented by contacting the skin with a chilled sapphire tip transparent to laser light. The combination of longer pulse widths and the unique contact cooling system reduces skin damage and allows for higher fluences to be safely used on darker skin.

Problematic and excessive hair growth are seen more commonly in many ethnic populations, including South American, African, Asian-Pacific, Middle Eastern, Mediterranean and African-American subjects. Pseudofolliculitis barbae (PFB), "beard bumps" and ingrown hair is a common disorder in African-American, African-Caribbean and African subjects with tightly curled or coiled facial hair. In PFB, curved hairs emerge from curved follicles at an acute angle and penetrate the nearby skin causing a reaction that is characterized by papules, pustules or small nodules at the point of reentry. Current treatments including plucking, waxing, depilatories, and electrolysis increase the incidence of unwanted side effects (hyperpigmentation and scarring) in this group of patients and are not effective.

Study Design

The primary objective of this long term, prospective study was to investigate the safety and effectiveness of a very long pulsed (100 ms) diode laser in the permanent reduction of coarse pigmented hair for darker-skinned subjects. This paper reports and compares the 100 ms pulse duration to the 30 ms pulse duration. The effects of laser epilation were evaluated for various fluences (15-100 J/cm^2), pulse durations (30 and 100 ms) and all Skin Ethnic Color Types (ECT).

Forty subjects, 25 females and 15 males, with coarse, dark hair on their thigh and backs were treated.

The study device used in this study was a LightSheer^2 high power diode laser modified to produce variable pulse durations (20-200ms) and

a range of fluences (15-100 J/cm^2).

Twenty-two test sites per subject were marked on the subject's thighs with micro-tattoos or anatomic landmarks to ensure the exact location of test sites at follow-up visits. Six of the sites were treated with the 100 ms pulse width, four with the 30 ms pulse width, and one was the control site. The other 11 sites were for additional pulse width and fluence combinations.

Hairs at each site were trimmed to a uniform 5 mm length using clippers, and the skin was cleaned with isopropanol. Digital images of the treatment sites were taken at each visit. A couple-charged-device (CCD) video camera with photographic ring flash and frame-grabber was used to provide high-resolution hair imaging. The camera was connected to a computer with image acquisition hardware and image analysis software. The number of hairs was counted in each test area before laser treatment and at each follow-up visit. Hair growth, hair shaft diameter and associated epidermal side effects were assessed before laser treatment and at 1, 2, 3 and 6 months following treatment.

Investigators visually assessed skin response, including hypopigmentation, hyper-pigmentation, erythema and edema, using a response grading scale of 0-3 (none/absent to full/severe). Textural changes were graded as 0 (absent) or 1 (present).

Hair regrowth was defined as the percentage of terminal hairs present after treatment, compared with the number before treatment, and was calculated for each site at each follow-up visit.

Results

For both pulse widths and for all skin types long-term hair loss after laser treatment was strongly correlated with fluence levels. The mean percentage hair regrowth at 6 months after a single treatment for each pulse width, fluence level and skin type is shown in Table 2 and Figures 1A and 1B. Patient photographs before and after treatment are shown in Figures 2 and 3. Hair shaft diameter ranged from 50-130 um in size.

Transient pigment changes were the most common side effects. A pulse duration of 100 ms and a fluence of 30 J/cm^2 could be safely used on all patients, except for Skin ECT VI subjects who all demonstrated epidermal side effects at the 1 month follow up period. Side effects increased with higher fluences, but at any given fluence was significantly reduced with longer pulse durations.

The tolerated range of fluences for the 100 ms pulse widths, based on data from this study, is shown in Table 3. The lower (starting) fluences are similar to the recommended settings for shorter pulse widths (such as 30 ms). However, the fluence levels for the 100 ms pulse width can be increased to improve efficacy without compromising safety. These tolerated ranges are based on the Skin Ethnic Color Type (ECT). Skin ECT IV includes light-brown skinned subjects (e.g. Asians, Hispanics, Middle Eastern, Asian-Pacific, African-Americans, etc.). Skin ECT V includes medium brown subjects (e.g. Hispanics, Middle Eastern, Asian-Pacific, and African Americans). Skin ECT VI includes dark brown subjects (e.g. Africans, Asian-Pacific, and African-Americans).

With Skin Types I-IV of the ECT scale, the typical clinical endpoint is perifollicular edema and erythema. This clinical endpoint, although often observed, was not always present in Skin Types ECT V-VI.

Very dark-skinned patients (Skin ECT VI) can still get epidermal damage (blistering) at the lowest fluence tested (15 J/cm^2). Therefore it is recommended, even at the 100 ms pulse width, to be very cautious with Skin ECT VI and to do 100 ms test spots starting at 10 J/cm^2 before attempting to treat their elective sites. For these patients, procedures such as sun avoidance, pretreatment with bleaching agents or chemical depilatories of the hair shaft may help to reduce side effects at higher fluences and thus improve the efficacy of the procedure.

2. Provided by Palomar Medical Technologies, Burlington, MA

Table 2: Percentage Hair Regrowth at 6 Months (Single Treatment)				
	Skin Ethnic Color Type			
Pulse duration/fluence	**ECT I - II**	**ECT III-IV**	**ECT V**	**ECT VI**
30 ms / 15 J/cm^2	82 - 87	75 - 83	93	81
30 ms / 30 J/cm^2	76 - 78	69 - 73	81	--
30 ms / 45 J/cm^2	70 - 71	68 - 83	67	--
30 ms / 60 J/cm^2	65 - 67	68 - 69	50	--
100 ms / 15 J/cm^2	86 - 90	84 - 97	82	81
100 ms / 30 J/cm^2	71 - 74	74 - 89	87	87
100 ms / 45 J/cm^2	61 - 73	67 - 68	68	76
100 ms / 60 J/cm^2	61 - 63	52 -67	72	--
Control	97	102	100	98

FIGURE 1A

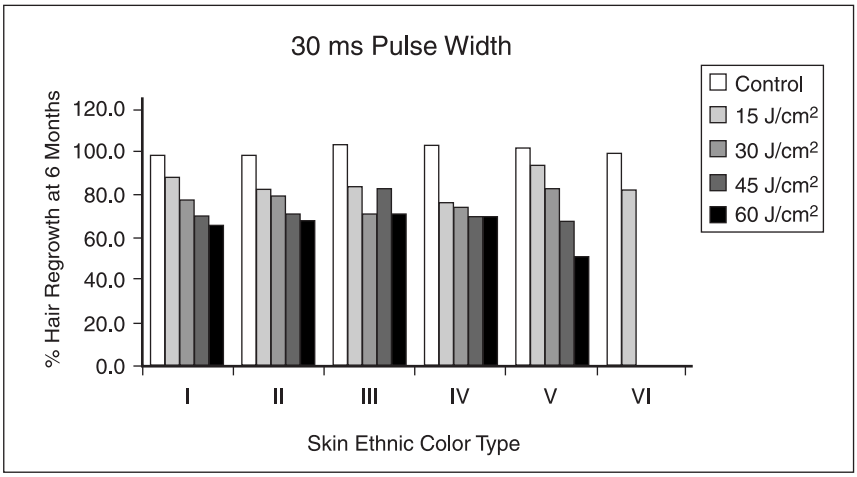
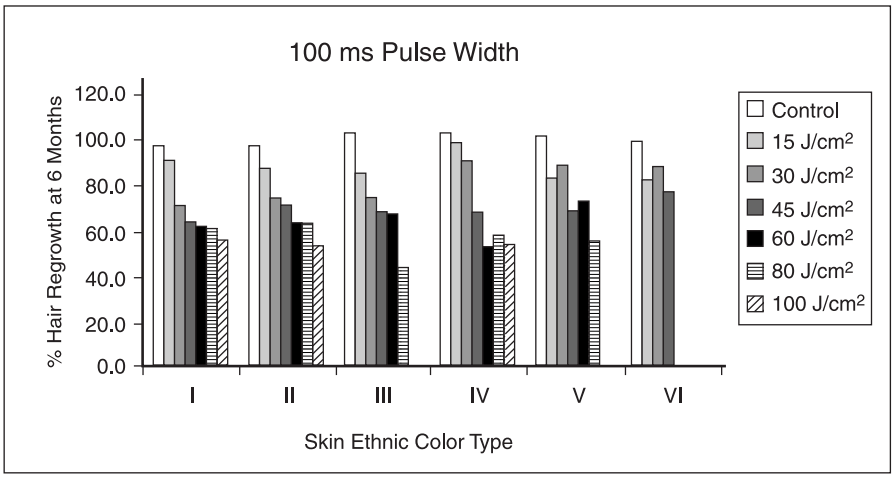
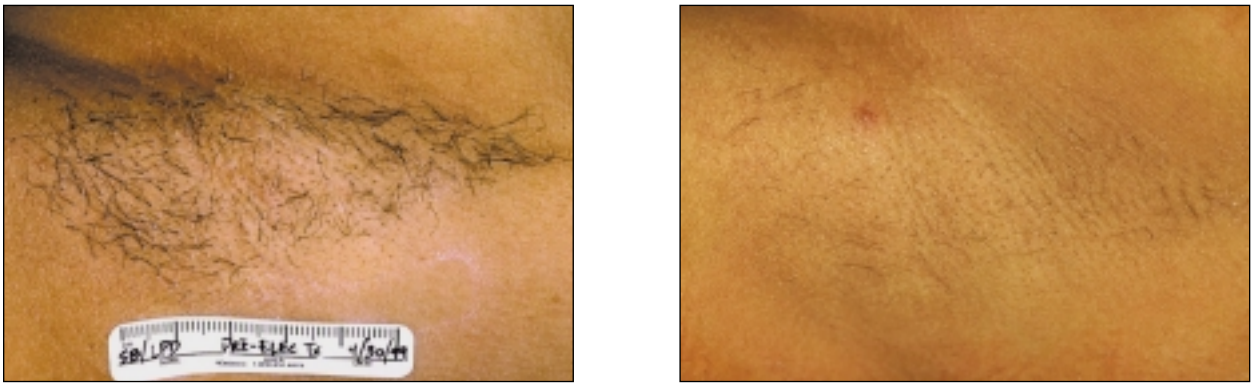


FIGURE 1B



FIGURES 2A AND 2B



39 year old Skin Ethnic Color Type V patient, Axilla, 100 ms, 30 J/cm^2, 3 treatments (1 month apart). Baseline and 6 months after last treatment.

FIGURES 3A AND 3B



35 year old Skin Ethnic Color Type V patient, Face, 100 ms, 30 J/cm^2, 3 treatments (1 month apart). Baseline and 3 months after last treatment. Notice that the hairy nevus has also been removed.

Table 3: Tolerated Fluences at 100 ms Pulse Width

Skin Ethnic Color Type (ECT)	Skin Color	Tolerated Fluences
I	Light white	15-60 J/cm^2
II	Medium white	15-60 J/cm^2
III	Dark white	15-45 J/cm^2
IV	Light brown	15-40 J/cm^2
V	Medium brown	10-35 J/cm^2
VI	Dark brown	Try 10 J/cm^2 test spot

Conclusions

• An 800 nm diode laser with contact cooling and very long pulse widths provides effective, long-term reduction of medium to coarse pigmented hair, even in darker-skinned subjects including Skin ECT V-African Americans.

• The treatment demonstrated two different effects on hair growth—short-term hair growth delay and permanent hair reduction. Each treatment is additive to the effects of another treatment. In addition, when regrowth occurs, the hair is normally thinner and lighter.

• Both the efficacy and risk of side effects of laser treatment increase with increasing fluences. By matching pulse duration and fluence levels to specific hair color, skin color and skin type, the laser can be effectively used to treat the widest range of patients.

• Very long pulse durations allow for all skin types to tolerate substantially higher fluences. Pulse durations longer than 100 ms may be required to safely and effectively treat Skin ECT VI patients.

• Caution should be exercised when using very long pulse widths to treat dense hair areas, because of thermal conduction between closely adjacent hair follicles.

• The very long-pulsed diode laser is effective for darker-skinned subjects (up to and including Skin ECT V), because higher fluences can be safely used with the 100 ms pulse width.

• These longer pulse durations are most effective on medium to coarse hairs (>50 um).

Although not specifically designed to be tested in this study, the very long-pulsed diode laser can be effectively used for the treatment of PFB in darker-skinned (up to Skin ECT V) patients. Because the longer pulse widths provide effective hair reduction for these patients, this leads to a decrease in the papules and pustules associated with this condition.

As with any laser procedure, treatment with the very long-pulsed diode laser should be started cautiously on test spots and the fluence increased gradually, taking into consideration the body area being treated, the amount of skin pigmentation and the hair density in each area. A delay of at least one hour should elapse prior to evaluation of test spots.

Selected References

1. Absten GT, Joffe SN. Lasers in Medicine. An Introductory Guide. 2nd Ed., Chapman and Hall: London, 1988.
2. Anderson RR. Laser-Tissue Interactions. In: Cutaneous laser surgery: the art and science of selective photothermolysis. Goldman MP, Fitzpatrick RE, eds. St. Louis: Mosby-Year Book, 2nd Ed., 1998:1-18.
3. Anderson RR, Parish JA. Selective photothermolysis: precise microsurgery by selective absorption of pulsed radiation. Science 1983;220:524-527.
4. Anderson RR, Parrish JA. The optics of human skin. J Invest Dermatol 1981;77:13.
5. Anderson RR. Polarized light examination and photography of the skin. Arch Dermatol 1991;127:1000-1005.
6. Bertolino AP, Klein LM, Freedberg IM. Biology of hair follicles. In Fitzpatrick TB, et al., eds. Dermatology in General Medicine. 4th Ed. McGraw-Hill: New York, 1993.
7. Dierickx CC, Grossman MC, Anderson RR. Long pulsed ruby laser hair removal. Lasers Surg Med 1997;S9:167.
8. Dierickx CC, Grossman MC, Farinelli WA, Anderson RR. Permanent hair removal by normal-mode ruby laser. Arch Dermatol 1998;134:837-844.
9. Dierickx CC, Alora MB, Dover JS. A clinical overview of hair removal using lasers and light sources. Dermatologic Clinics 1999;17:357-366.
10. Farmer ER, Hood AF. Pathology of the Skin. Appleton and Lange: East Norwalk, CT, 1990.
11. Goldberg DJ. Topical solution-assisted laser hair removal. Lasers Surg Med 1995;7S:47.
12. Grossman MC. What is new in cutaneous laser research? Dermatol Clin 1997;15:1.
13. Kligman AM. The human hair cycle. J Invest Dermatol 1959;33:307.
14. Nanni CA, Alster TS. Laser-assisted hair removal: optimizing treatment parameters for hair removal using a topical carbon-based solution and 1064 nm Q-switched Neodymium:YAG laser energy. Arch Dermatol 1997;133:1546-1549.
15. Ross EV, Ladin Z, Kreindel M, Dierickx C. Theoretical considerations in laser hair removal. Dermatologic Clinics 1999;17:333-355.

16. Sahoo A. The history of laser hair removal. Newsletter of the International Guild of Professional Electrologists, Spring 1997.
17. Tse Y. Hair removal using a pulsed-intense light source. Dermatologic Clinics 1999;17:373-386.
18. Wheeland RG. Clinical uses of lasers in dermatology. Lasers Med Surg 1995;16:2.
19. Wheeland RG. Laser-assisted hair removal. Dermatol Clins 1997;15:469.
20. Williams RM, Christian MM, Moy RL. Hair removal using long-pulsed ruby laser. Dermatologic Clinics 1999; 17:367-372.
21. Altshuler GB, Zenzie HH, Erofeev AV, Smirnov MZ, Anderson, RR, Dierckx C. Contact cooling of the skin. Phys Med Biol 1999;44:1003-1023.