

Efficacy and Safety of Hair Removal with a Long-Pulsed Diode Laser Depending on the Spot Size: A Randomized, Evaluators-Blinded, Left-Right Study

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Background: The efficacy of the long-pulsed diode laser (LPDL) in hair removal is determined with various physical parameters. Recently, LPDLs with a larger spot size are commercially available; however, the independent effect of spot size on hair removal has not been studied. **Objective:** This study aimed to compare the efficacy of the LPDL in hair removal depending on the spot size. **Methods:** A randomized, evaluators-blind, inpatient comparison (left vs. right) trial was designed. Ten healthy Korean women received three hair removal treatment sessions on both armpits with the 805-nm LPDL and followed for 3 months. A 10×10 mm handpiece (D1) or a 10×30 mm handpiece (D3) was randomly assigned to the right or left axilla. The fluence, pulse duration, and epidermal cooling temperature were identical for both armpits. Hair clearance was quantified with high-resolution photos taken at each visit. Postprocedural pain was quantified on a visual analogue scale. Adverse events were evaluated by physical examination and the patients' self-report. **Results:** The mean hair clearance at 3 months after three treatment sessions was 38.7% and 50.1% on the armpits treated with D1 and D3, respectively ($p=0.028$).

Procedural pain was significantly greater in the side treated with D3 ($p=0.009$). Serious adverse events were not observed. **Conclusion:** Given that the pulse duration, fluence, and epidermal cooling were identical, the 805-nm LPDL at the three times larger spot size showed an efficacy improvement of 29.5% in axillary hair removal without serious adverse events. (*Ann Dermatol* 27(5) 517~522, 2015)

-Keywords-

Hair, Hair removal, Long pulsed diode laser, Laser spot size

INTRODUCTION

While loss of hair is a common aesthetic issue in men¹, unwanted growth of hair on certain body parts is a frequent concern in women. Nowadays, with increased preference of a "neat image" among men, growing numbers of men want to remove hair on their chest, arms, and legs, as well as their beard hairs.

Unwanted body hair can be removed by shaving, waxing, plucking, or by using chemical depilatories; however, these methods are effective only temporarily and the hair grows back in a short time. Laser hair removal was introduced in 1996 by Grossman et al.², who reported hair removal with a ruby laser, and has become more popular for its long-lasting effect³. Currently, there are various devices available for hair removal, including the long-pulsed alexandrite, diode, and Nd:YAG lasers, and intense pulsed light (IPL) systems³⁻⁵.

Among these commercially available lasers, the 800~810 nm long-pulsed diode laser (LPDL) is one of the most commonly used devices. Compared with the ruby (694.3 nm) or alexandrite (755 nm) lasers, the LPDL is less absorbed by melanin in the epidermis, making it effective for

Received December 5, 2014, Revised February 5, 2015, Accepted for publication February 7, 2015

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hair removal even in the darker skin types⁶⁻¹¹. The efficacy of LPDL in hair removal is determined with various physical parameters, including the wavelength, pulse duration, fluence, spot size, treatment interval, and number of treatment sessions, as well as by the patient's individual characteristics, such as skin color, hair color, hair thickness, and the treated site^{6,10,12-15}. LPDLs have thus far only been available with a small spot size (around 1 cm in diameter)^{4,7,8,11,13-15}, which is associated with large energy loss due to scattering and with a high demand of time and operators' efforts for hair removal in large areas. Recently, LPDLs with a bigger spot size have been developed and are commercially available. To evaluate the impact of spot size on the efficacy of the LPDL in hair removal, we compared the outcomes and adverse events of axillary hair removal by using small and large spot sizes under the condition that fluence, pulse duration, and epidermal cooling temperature are identical.

MATERIALS AND METHODS

Subjects

This study was set up as a randomized, evaluators-blind, inpatient comparison (left vs. right) trial, and was approved by the institutional review board of Seoul National University Hospital (IRB-H-1312-030-539). Before participating in this study, written informed consent was obtained from each subject. Ten females with ages ranging from 24 to 50 years were enrolled in the study (Table 1). All of the subjects were Korean, with Fitzpatrick skin type II-IV¹⁵, and with black axillary hair. Their usual hair removal methods before the study were shaving, plucking, and waxing. None of the subjects was pregnant or lactating, and all were asked to use a reliable method of birth control throughout the course of the study if they were of childbearing age. The exclusion criteria were as follows: any severe medical problems including hormonal dis-

orders, bleeding disorders, and cardiac and renal disorders; any dermatologic condition affecting the axilla, including dermatitis, pigmented disorder, tumors, or keloids; any history of laser axillary hair removal; use of hair removal wax or cream on the axilla within the previous 1 month; use of any systemic retinoid within the previous 6 months; and immune deficiency disorder or use of immunosuppressive agents.

Laser hair removal in the axilla

Each subject received hair removal treatment on both armpits with an 805-nm LPDL (Advantage; Lutronic Corporation, Goyang, Korea), with a 10×10 mm handpiece (D1) or 10×30 mm handpiece (D3) being randomly assigned to the right or left axilla. The fluence and pulse duration were identical for both armpits, namely 25~33 J/cm² (median, 27 J/cm²) and 30~45 ms (median, 40 ms), respectively. The epidermal cooling temperature was also identical at 3°C and the operation room temperature was maintained between 20°C and 22°C. The subjects received three treatment sessions at 1-month intervals. In each session, a single pass of laser treatment was conducted with 10% overlap between treated areas. All procedures were conducted by a dermatologist who had ample experience of hair removal.

Efficacy and safety assessment

Hair clearance was quantified with high-resolution digital photos taken at baseline (shortly before the first session), shortly before the second and third sessions, and at 1 and 3 months after the third session.

The number of hairs in each photo was counted by using magnified screen images. Three evaluators, who were medical doctors, independently counted the number of hairs and the mean value was used for the evaluation. To keep the evaluators blind, no information was given about the subject, the axillary side, or the chronology of the photographs. Hair clearance from each axilla, a main outcome measure in this study, was defined as the number of removed hairs divided by the number of initial axillary hairs, and expressed as a percentage.

Postprocedural pain was quantified on a visual analogue scale (VAS) ranging from 0 (no pain) to 10 (intolerable pain) immediately after the first session. Adverse events were evaluated at each visit by means of physical examination and through the patients' self-report.

Statistics

Data analysis was performed by using the IBM SPSS Statistics ver. 19.0 (IBM Co., Armonk, NY, USA). The hair clearance was compared between the D1-treated and

Table 1. Demographic characteristics of the subjects

Characteristic	Value
Subjects	10
Age (yr)	25.5 (24~50)
Fitzpatrick's skin type	
II/III/IV	4/4/2
Hair removal method before study	
Shaving	6
Plucking	2
Shaving and plucking	1
Waxing	1

Values are presented as number or median (range).

D3-treated axillae by using the Wilcoxon signed rank test. $p < 0.05$ was considered significant.

RESULTS

All 10 subjects successfully completed the study, including the follow-up.

Efficacy of hair removal with LPDL

In the gross examination after completing the laser procedures, both sides showed good results in 9 subjects out of 10 whether treated with the small or the large spot size (Fig. 1). At 1 month after the first session, the mean hair clearance with the D1 and D3 handpieces was 62.1% ($n = 10$; median, 64.4%; range, 24.8% ~ 85.6%) and 62.3% ($n = 10$; median, 62.9%; range, 25.3% ~ 86.7%), respectively; both small and large spot sizes were significantly effective for hair removal with LPDL ($p = 0.005$). The effect of LPDL was maintained significantly up to 3 months after completing three treatment sessions (Fig. 2A).

The mean hair clearance at 1 month after the third session was 65.5% (median, 73.1%; range, 22.2 ~ 86.0) with the D1 handpiece and 77.4% (median, 80.6%; range, 45.9 ~

94.7) with the D3 handpiece, which was statistically significantly different between the groups ($p = 0.022$). At 3 months follow-up, the mean hair clearance was 38.7% (median, 45.2%; range, -8.7% ~ 66.5%) and 50.1% (median, 56.3%; range, 7.3% ~ 74.9%) for the D1 and D3 handpieces, respectively ($p = 0.028$; Fig. 2A).

Three of the 10 subjects were followed for up to 6 months after completing the three sessions, and the hair removal effect was maintained (Fig. 1). The mean hair clearance was 40.4% ($n = 3$; median, 50.6%; range, 7.4% ~ 63.3%) on the side treated with the D1 handpiece and 53.7% ($n = 3$; median, 60.0%; range, 33.2% ~ 68.1%) on the side treated with D3 the handpiece, with both sides showing higher clearances compared with 3 months after the third session (Fig. 2B).

Discomfort and adverse events

The most common discomfort during laser hair removal was pain. A VAS was used in this trial to measure the pain in both sides shortly after the first treatment session. The mean VAS score was 3.1 (median, 3.0; range, 0.5 ~ 6.3) with the D1 and 4.3 (median, 4.7; range, 1.1 ~ 6.9) with the D3 handpiece, showing a statistically significant differ-



Fig. 1. Photographs of axillary areas treated with the small- and large-spot long-pulsed diode laser at baseline, after three treatment sessions, and at the 6-month follow-up in the same subject.

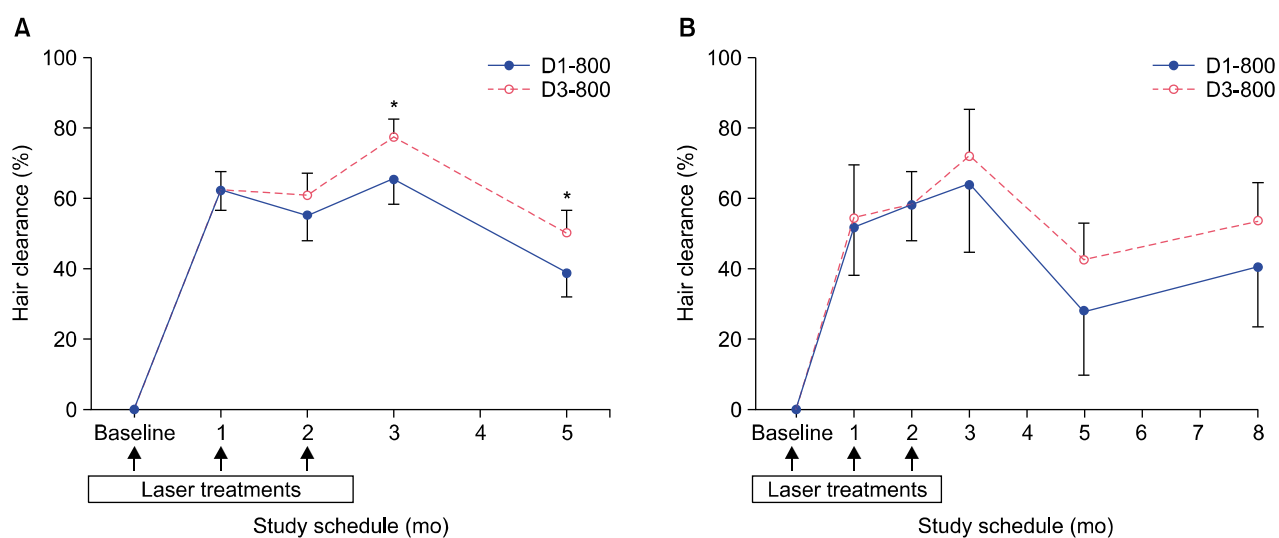


Fig. 2. Hair clearance of long-pulsed diode laser-treated axillary areas (A) in all 10 subjects and (B) in three subjects followed for up to 6 months after completing the three sessions. * $p < 0.05$ between areas treated with a 10×10 mm handpiece (D1) and a 10×30 mm handpiece (D3).

ence ($p = 0.009$). One subject experienced post-inflammatory hyperpigmentation on both sides after the third session; no other serious adverse events were observed.

DISCUSSION

To the best of our knowledge, this is the first comparative clinical trial to evaluate the impact of spot size on the efficacy of the LPDL in hair removal. Previous reports on large-spot-size LPDLs did not have a control with a small spot size⁹, or used different fluences as well as spot size for each treatment group, precluding the evaluation on the impact of spot size alone¹⁵. On the other hand, we could perform hair removal with identical pulse duration and fluence, independent of the spot size, because the LPDL device (Advantage) used in this study allowed high fluence even with the large spot size. Unlike most previous studies that measured hair density per unit area, we measured the total hair count over the whole armpit to reduce measurement error and faithfully reflect the clinical significance.

The mechanism of laser hair removal can be explained by the selective photothermolysis and heat transfer theories^{12,16-18}. A selective damaging of target tissue can be achieved with pulse durations shorter than the thermal relaxation time of that tissue by minimizing heat transfer to the surrounding tissues¹⁶. In case of hair follicles, the energy absorbed by melanin in the hair matrix and shaft should be transferred to the surrounding tissues to achieve selective tissue destruction by thermal injury¹³. In other words, laser beam irradiation with a wavelength absorbed

by melanin and a pulse duration slightly longer than the thermal relaxation time will create heat that will cause damage to the stem cells or papilla cells, or both, in the hair follicle.

Meanwhile, the melanin in the epidermis competitively absorbs the same wavelength of light as the one used for hair removal. Given that the melanin concentrations are under the same condition, darker skin types are more prone to thermal injury from the epidermal absorption of laser energy, and may benefit less from the hair removal due to reduced energy absorption in the hair follicle³. However, as darker skin tends to have a higher melanin concentration in the hair, simply having dark skin would not be the only reason for a decreased hair removal effect. In this context, it would be imperative to apply the optimal physical laser parameters for safe and effective hair removal.

Spot size is one of the most important laser physical parameters that can affect the efficacy of hair removal. The energy of the laser beam when it makes contact with the skin is not completely absorbed in the tissue due to reflection or scattering. Theoretically, less scattering in the tissue means more efficient transfer of energy to the target^{17,18}. The scattering of a laser beam is affected by the spot size¹⁸. For example, when a spot size is increased from 5 mm to 12 mm, the optical transmittance of tissue is nearly doubled¹⁹. When the fluence is identical, a larger spot size induces an increase in energy absorption by the melanin in hair, causing greater thermal injury to the hair follicle. Nouri et al.²⁰ reported that an 18 mm and a 12 mm spot size showed a 52.2% and a 41.9% mean hair re-

duction for axillary hair removal with an alexandrite laser, respectively, which means that the alexandrite laser at the 2.25 times larger spot size showed an efficacy improvement of 24.6%. Although the wavelength of the laser is different, this result is consistent with ours in which the LPDL at the three times larger spot size showed an efficacy improvement of 29.5% in axillary hair removal. Eremia and Newman¹⁷ found that the alexandrite laser with a 12 mm spot size induced more pain than that with 8 mm spot size.

In the current study, the hair clearance after three sessions of LPDL treatment was superior with the larger spot size. This is consistent with a previous study reporting that a large-spot-size LPDL could delay hair regrowth¹⁵. As laser hair removal requires repeated procedures on a large area, a large spot size would be also helpful for reducing the procedure time. However, the larger-spot-size LPDL caused more pain during hair removal in this study, as was the case with the alexandrite laser cited above¹⁷, suggesting that a larger spot size would increase the degree of photon absorption by tissues, and thereby cause greater thermal injury.

It is worth noting that the hair clearance after three treatment sessions had decreased at 3 months after the final treatment, compared with that at 1 month, and then increased again at 6 months in the three subjects who were followed for up to 6 months after completing the three sessions (Fig. 2B). Similar results were observed in previous studies^{21,22}. The reduced clearance at 3 months could be explained by treatment-induced synchronization²¹; most hair follicles enter the telogen phase shortly after laser treatment and then the anagen phase simultaneously about 3 months later, temporarily appearing to have low hair clearance and more hairs. When the cycle of each hair follicle undergoes randomization, then the hair clearance would be increased without further treatment. This phenomenon is observed clinically and can be explained when all strands of hair that were left after laser hair removal with a sufficiently high fluence were induced to enter the telogen phase simultaneously, and may not be observed when a low fluence or an IPL system with a low absorption rate was used.

There are several limitations to this study. First, the study population was small. Second, the operators could not be blinded because of the nature of the LPDL treatment, although the operators' skill, such as the extent of pressure they apply to the skin, may create a difference in the hair removal effect. Third, there is lack of quantitative analysis on the association between spot size and fluence for producing an identical hair removal effect. We are planning a further study to investigate how high the fluence should

be to produce an identical effect from the small-spot-size LPDL as with the large-spot-size LPDL.

In conclusion, the large-spot-size LPDL used in the present study was more effective for axillary hair removal without serious adverse events, compared with the small-spot-size LPDL. This study should prove useful for clinicians in selecting physical parameters for effective and safe laser hair removal.

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