# Photoepilation Results of Axillary Hair in Dark-Skinned Patients by Intense Pulsed Light: Comparison between Different Wavelengths and Pulse Widths

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BACKGROUND Recently, intense pulsed light (IPL) sources have been shown to provide long-term hair removal.

OBJECTIVE This study examined the photoepilatory effects of different wavelengths and pulse width application in the same IPL device and compared their efficiencies in Asian skin.

METHODS Twenty-eight Korean women were treated using hair removal (HR) (600–950 nm filter) and 27 using HR-D (645–950 nm filter) in the axillary area. Four treatments were carried out at intervals of 4 to 6 weeks; follow-ups were conducted 8 months after the last treatment. Mean energy settings were 14.9 ± 2.0 J/cm$^2$ for HR and 17.1 ± 0.6 J/cm$^2$ for HR-D. Longer pulse widths were applied in case of HR-D treatment. Hair counts and photographic evaluation of skin sites were made at baseline and at the last follow-up. Final overall evaluations were performed by patients and clinicians.

RESULTS Average clearances of 52.8% and 83.4% were achieved by HR and HR-D, respectively. No significant adverse effects were reported after HR-D treatment. One case each of hypopigmentation and hyperpigmentation was reported for HR.

CONCLUSION An IPL source removing 45 nm of the emitted spectra and applying a longer pulse width was found to provide a safer and more effective means of photoepilation in Asian patients.

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Conventional hair removal techniques include shaving, waxing, tweezing, chemical depilation, and electrolysis.[1,2] However, all of these methods result in temporary hair removal and are sometimes irritating. In recent years, the use of lasers to remove unwanted body hair has attracted considerable interest, and a variety of wavelengths have been shown to remove hair effectively on the scientific basis of selective photothermolysis.[3,4] The currently used photoepilation devices include ruby, alexandrite, long-pulsed neodymium:yttrium-aluminum-garnet, diode lasers, and intense pulsed light (IPL).[4,5] However, the management of dark-skinned phenotypes remains problematic because melanin pigments in the epidermis competitively absorb light intended for hair follicle melanin pigments, the primary target of photoepilation.[6–10]

IPL is a high-intensity polychromatic light. Unlike laser systems, these flashlamps work by using incoherent light in the wavelength range of 515 to 1,200 nm,[11] and by using different filters, a wide range of wavelengths are possible for IPL systems. Various studies have reported that 33 to 80% hair reduction is achieved over follow-up periods ranging from 12 weeks to 21.1 months.[11–16] However, direct comparison among studies is not possible because of differences in treatment device, wavelength application, and treatment condi-

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tions. Previous hair removal studies using second-generation IPL sources (Ellipse Flex, Danish Dermatologic Development, Hoersholm, Denmark) in Caucasian skin types by Troilius and Troilius determined efficacy by using hair counts and found 80.2% removal in the bikini area 8 months after a final, fourth treatment.[12]

In this study, the efficacy and safety of the same IPL system (Ellipse Flex) were examined in Korean women. Hair removal was evaluated, and the efficacy and safety of a new applicator emitting 645 to 950 nm light were compared with those of the conventional applicator emitting 600 to 950 nm light to find the most optimal treatment conditions for photoepilation in dark-skinned patients.

## Patients and Methods

### *Study Groups*

The study group consisted of 55 female volunteers who wished to remove axillary hair. All volunteers received verbal and written information about the objectives, procedures, and risks associated with the study, and written consent was obtained from all subjects before enrolment. Twenty-eight volunteers were treated with IPL sources emitting 600 to 950 nm, with a mean of 800 nm hair removal (HR), and 27 volunteers were treated with the same IPL source emitting 645 to 950 nm, with a mean of 830 nm (HR-D). Volunteers treated with HR were age 21 to 47 years, with a mean age of 28.7 years, and HR-D patients were age 21 to 43 years, with a mean age of 29.9 years. Areas to be treated were designed to cover all axillary hair-growing areas. Fitzpatrick skin types ranged from II to IV (II 1/III 20/IV 7) for HR and from III to IV (III 11 and IV 16). Volunteers with a history of sunburn within 4 weeks before the treatment were excluded. Waxing, chemical depilatories, and suntanning were discontinued at least 4 weeks prior to and during treatment and for 4 weeks following treatment.

### *Photoepilation and Clinical Assessment*

Before IPL treatment, hairs in the treatment areas were shaved. This IPL device does not have any epidermal cooling device. For that reason, just before the treatment, cooled optical coupling gels were applied evenly onto the treated area to prevent any epidermal injuries. All patients received four sessions of treatment at 4- to 6-week intervals. The treatment parameters used in this study are shown in Table 1. A 1 $cm^2$ grid was used to count hairs at baseline and at 8 months after the last (fourth) treatment. Treatment sites were localized with respect to a defined anatomic landmark and were confirmed by referring to standardized photographs. Hairs were counted from magnified photographs (3 × 5 inches) by one of two investigators in a blinded manner. Hair removal efficiencies (HREs) were calculated as percentages of the number of hairs removed versus baseline. Side effects and any pain (using visual analogue scales of 0–10) experienced during the procedures were recorded at each visit. At the last follow-up, patients and a clinician performed a final overall evaluation of the hair reduction treatment by using a 6-point scale (ie, worse; none; poor, 0–24%; fair, 25–49%; good, 50–74%; excellent, 75–100% reduction). Additional beneficial effects, for example, pigmented spots and skin texture, were documented.

### *Statistical Evaluation*

The Wilcoxon test for paired differences was used to compare be-

**TABLE 1. Treatment Parameters Used in This Study**

| | *HR* | *HR-D* |
|---|---|---|
| Wavelength | 600–950 nm | 645–950 nm |
| Pulse duration | Thick hair: 40 ms<br>Medium hair: 20 ms | Thick hair: 50 ms<br>Medium hair: 25 ms |
| Fluence | Just enough to give a perifollicular edema and redness after 3 min waiting time<br>Maximum fluence for volunteers to endure | |
| Treatment interval | 4–6 wk | |
| Follow-ups | 8 mo after the last treatment | |

HR = hair removal

fore and after hair counts and final overall evaluations made by clinicians and subjects. The Student's *t*-test was used to compare the effects of HR and HR-D and the skin type results obtained for a given light source. Statistical significance was accepted at the 5% level.

## Results

Of the 28 volunteers treated with HR, 24 (II 1/III 16/IV 7) successfully completed the four-treatment protocol and the 8-month follow-up after the fourth treatment. Of the 27 subjects treated with HR-D, 24 (III 9 and IV 15) completed the four-treatment protocol and the 8-month follow-up.

All study subjects showed statistically significant hair reduction after treatment ($p < .001$) (Figure 1). There were no statistically significant differences in initial hair counts between each group ($p = .581$). The initial hair counts within the assessed area (1 $cm^2$) in the HR-treated group were 15.1 ± 3.5 and 14.7 ± 3.8 in the HR-D-treated group. The number of hairs within the 1 $cm^2$ grid at the last follow-up was 7.2 ± 3.7 in the HR-treated group and 2.5 ± 1.8 in the HR-D-treated group, which showed statistically significant differences ($p < .001$) (Table 2). Overall HRE was 52.8% ± 21.7% for HR and 83.4% ± 10.9% for HR-D. HRE for HR-D was statistically significantly higher than for HR ($p < .001$). Mean fluences applied during treatment were 14.9 J/$cm^2$ ± 2.0 J/$cm^2$ for HR and 17.1 J/$cm^2$ ± 0.6 J/$cm^2$ for HR-D, which was also significantly different. Pain levels during procedures as reported by subjects were 6.5 ± 2.4 for HR and 3.3 ± 1.3 for HR-D, which was significantly different ($p < .05$) (Table 3). Final overall evaluations by study subjects and clinicians are detailed in Figure 2.

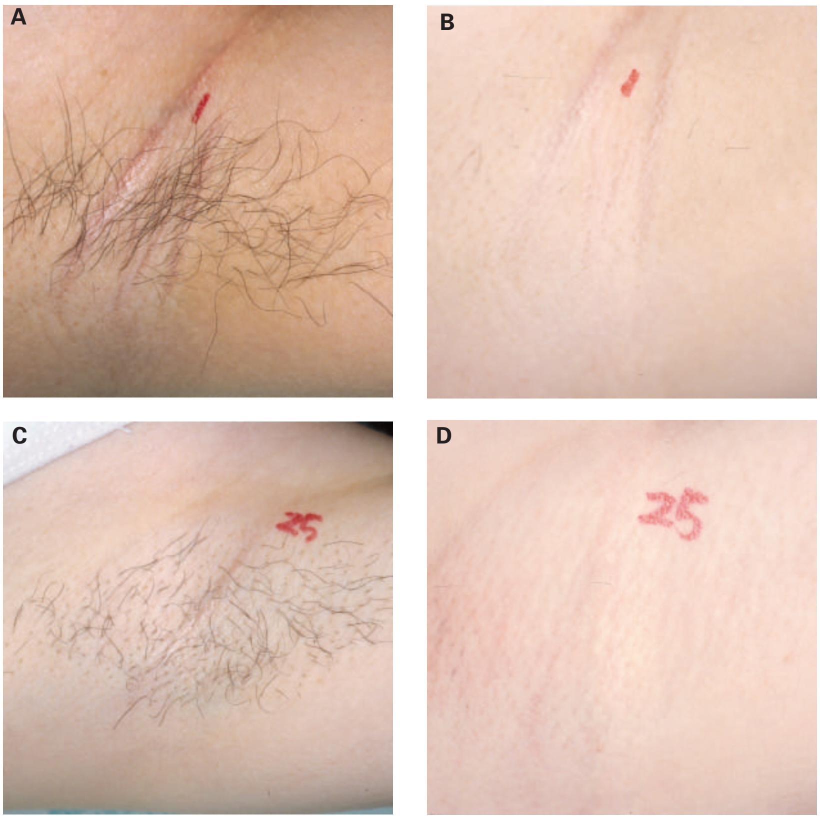


**Figure 1.** A and C show pretreatment status. B and D demonstrate post-treatment status 8 months after the last treatment. Volunteers refrained from shaving for 4 weeks prior to their last follow-up. No prominently growing axillary hairs were observed in D; however, thinned axillary hairs are seen in B.

HREs according to skin type treated with HR were 61.5% in subjects with skin type II, who received a mean fluence of 17.0 J/$cm^2$; 46.5% in subjects with skin type III, who received 15.7 J/$cm^2$; and 40.3% in subjects with skin type IV, who received 13.0 J/$cm^2$. Significant correlations were found between applied fluences and HRE ($p < .01$). For HR-D, subjects with skin type III received an average fluence of 17.2 J/$cm^2$ and subjects with skin type IV received an average of 17.1 J/$cm^2$. HRE was not found to be dependent on skin type (skin type III, 80.1%, versus skin type IV, 85.4%) (Table 4).

In one volunteer (skin type III) treated with HR, perifollicular hyperpigmentation was observed at the third treatment session;

**TABLE 2. Hair Counts within the 1 cm² Grid at Baseline and 8 Months after the Last Treatment**

| | HR | | | HR-D | | |
|---|---|---|---|---|---|---|
| | *Pre-Tx* | *Post-Tx* | *HRE (%)* | *Pre-Tx* | *Post-Tx* | *HRE (%)* |
| 1 | 23 | 9 | 60.9 | 19 | 3 | 84.2 |
| 2 | 20 | 15 | 25.0 | 19 | 4 | 78.9 |
| 3 | 23 | 14 | 39.1 | 19 | 8 | 57.9 |
| 4 | 12 | 10 | 16.7 | 19 | 3 | 84.2 |
| 5 | 14 | 5 | 64.3 | 14 | 2 | 85.2 |
| 6 | 9 | 4 | 55.6 | 11 | 1 | 90.9 |
| 7 | 15 | 5 | 66.7 | 12 | 4 | 66.7 |
| 8 | 16 | 5 | 68.8 | 14 | 1 | 92.9 |
| 9 | 11 | 3 | 72.7 | 9 | 2 | 77.8 |
| 10 | 16 | 11 | 31.3 | 10 | 0 | 100.0 |
| 11 | 15 | 3 | 80.0 | 20 | 3 | 85.0 |
| 12 | 14 | 4 | 71.4 | 14 | 4 | 71.4 |
| 13 | 19 | 5 | 73.7 | 18 | 3 | 83.3 |
| 14 | 13 | 3 | 76.9 | 20 | 0 | 100.0 |
| 15 | 16 | 10 | 37.5 | 13 | 1 | 92.3 |
| 16 | 15 | 8 | 46.7 | 12 | 2 | 83.3 |
| 17 | 11 | 9 | 18.2 | 10 | 1 | 90.0 |
| 18 | 12 | 5 | 58.3 | 12 | 1 | 91.7 |
| 19 | 13 | 9 | 30.8 | 13 | 2 | 84.6 |
| 20 | 12 | 2 | 83.3 | 16 | 2 | 87.5 |
| 21 | 14 | 5 | 64.3 | 12 | 1 | 91.7 |
| 22 | 18 | 5 | 72.2 | 20 | 2 | 90.0 |
| 23 | 16 | 13 | 18.8 | 9 | 3 | 68.4 |
| 24 | 15 | 10 | 33.3 | 17 | 6 | 64.7 |
| Average | 15.1 | 7.2 | 52.8 | 14.7 | 2.5 | 83.4 |
| SD | 3.5 | 3.7 | 21.7 | 3.8 | 1.8 | 10.9 |

HRE = hair removal efficiency; Tx = treatment.
Initial axillary hair status is nearly the same between each group (Student's *t*-test, $p = .581$). HRE is calculated as a percentage of the number of removed hairs compared with the baseline count.

**TABLE 3. Hair Removal Efficiency after Treatment with HR or HR-D**

| | *HR* | *HR-D* |
|---|---|---|
| Skin type | II 1/III 16/IV 7 | III 9/IV 15 |
| Applied fluency (J/cm²) | 14.9 ± 2.0 | 17.1 ± 0.6** |
| Pulse width (ms) | 20, 40 | 25, 50 |
| Hair reduction (%) | 52.8 ± 21.7 | 83.4 ± 10.9** |
| Pain level | 6.5 ± 2.4 | 3.3 ± 1.3** |
| Side effects | 2/24 | None |

Applied fluence and percent hair reduction were significantly different for the HR and HR-D modalities. Pain levels were checked using a visual analogue scale by volunteers at each visit, and the results obtained also demonstrate that treatment with HR-D may reduce pain during the depilation procedure compared with HR.
Student's *t*-test, $*p < .05$; $**p < .01$.

thus, treatment was discontinued. In another volunteer treated with HR, mild hypopigmentation was observed at the second treatment session. This patient decided to continue treatment, and at the 9-month follow-up, her skin hypopigmentation had returned to a normal skin color. However, no adverse effect was observed during or after HR-D treatment.

Four subjects did not complete HR treatment; one complained of perifollicular hyperpigmentation, but the others gave no reason for cessation. Three volunteers did not complete the HR-D study owing to follow-up loss for unknown reasons.

## Discussion

The effectiveness of different optical depilation devices varies considerably owing to the different wavelengths, energy levels, pulse durations, and biologic variables, such as anatomic location, epidermal pigmentation, duration of the hair follicle cycle, and androgen status.[11,17] The target chromophores of photoepilation are the melanin-rich hair shafts and bulbs. However, competing chromophores exist, for example, epidermal melanin and other light-absorbing components, such as hemoglobin in blood vessels.[16,18] Asian skin has a higher epidermal melanin content than Caucasian skin and is more prone to epidermal injuries and adverse pigmentary reactions after IPL treatment. Therefore, the management of dark skin phenotypes remains problematic for laser- and IPL-assisted treatments.[5,19–21]

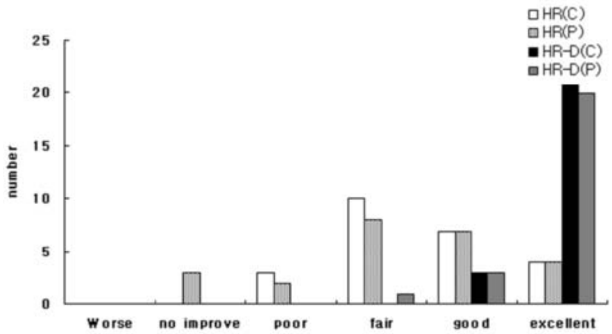


**Figure 2.** Final overall evaluations by volunteers and clinicians of the treatment results obtained using HR and HR-D. HR-D was awarded high final overall scores by patients and clinicians. Worse = no improvement; Poor = < 25% improvement; Fair = 25 to 50% improvement; Good = 50 to 75% improvement; Excellent = > 75% improvement. HR(C) = the final evaluation by the clinician in the patients treated with HR; HR-D(C) = the final evaluation by the clinician in the patients treated with HR-D; HR-D(P) = the final evaluation by the patients treated with HR-D; HR(P) = the final evaluation by the patients treated with HR.

**TABLE 4. Hair Removal Efficiency According to Skin Type**

| | HR | | HR-D | |
|---|---|---|---|---|
| *Skin Type* | *Fluence (J/cm²)* | *HRE (%)* | *Fluence (J/cm²)* | *HRE (%)* |
| II | 17.0 | 61.5 | | |
| III | 15.7 | 46.5 | 17.2 | 80.1 |
| IV | 13.0 | 40.3 | 17.1 | 85.4 |

HRE = hair removal efficiency.
No statistically significant differences in HRE or in applied fluences were observed between skin types III and IV treated with HR-D. On the other hand, HREs after HR treatment were found to be significantly dependent on skin type. Moreover, the clinical outcome in the HR-treated group clearly shows that higher fluence applications produced better HRE results.

An increasing number of studies have confirmed the long-term hair removal efficiency of IPL systems that emit a broad spectrum of longer wavelengths.[12–16,22–25] Flashlamp-assisted hair removal enables a wide choice of emitting wavelengths to be chosen simply by choosing different cutoff filters, thus, this modality may be effective in a wide range of skin types, especially in darker skins.[5,25] In published investigations of the IPL system, light spectra, pulse durations, number of pulses, fluence, and the use of skin cooling vary considerably, making direct comparisons difficult. Moreover, the evaluation of HREs has not been performed in the same IPL device with modification of treatment parameters under the same clinical condition. Also, the optimal conditions required for optical depilation using the IPL system in Asian skin have not been determined. In this study, the more optimal condition of high HREs in Asian skin was investigated with modification of wavelengths and pulse widths in the same IPL device under the same clinical condition.

HR emits a wavelength range of 600 to 950 nm (average wavelength 800 nm), whereas HR-D emits 645 to 950 nm (average wavelength 830 nm). The HR-D applicator was fitted with a lower cutoff filter (at 645 nm) and thus eliminated the shorter wavelength (600–645 nm) absorbed by epidermal melanin pigment. This probably reduced epidermal absorption and caused the treatment to be less painful. Table 4 showed that with the same wavelengths and pulse width applications, applied fluence may be the most important factor of HRE, which concurs with the report by Liew and colleagues.[21] The main limitation that prevents clinicians from applying higher fluences is pain occurring during the procedure[22] because as applied fluence is increased, treatment pain is also increased. Pain levels documented by volunteers were significantly higher during HR than HR-D treatment, which implies that wavelengths shorter than 600 to 645 nm are better absorbed by epidermal melanin and may evoke more pain to patients.

To achieve the selective destruction of target chromophores, appropriate pulse duration must be determined for laser- or flashlamp-assisted photoepilation.[26] The thermal relaxation time (TRT) is defined as the time taken for an increase in temperature to reduce by half of its peak value. A pulse time substantially longer than the TRT reduces heat conduction from the target to adjacent tissue,[9] whereas too short a pulse time is likely to develop an epidermal burn. The TRT of epidermal melanosomes is 1 to 2 milliseconds, and that of a hair shaft is 40 to 100 milliseconds.[14] Therefore, a pulse time between that of epidermal melanin and hair follicles is probably most effective for selectively destroying hair follicles without damaging surrounding tissues. However, the concept of an appropriate pulse time for hair removal is under debate. Recently, longer pulse widths were favored to improve clinical efficacy without significantly increasing the risk of adverse effects.[5,9,27,28] Diericks argued that the actual target during hair removal is not the pigmented structure but rather components removed from a pigmented structure, such as the follicular stem cells that lie in the hair follicle outer root sheath.[29] Pulses longer than the TRT of hair shafts were found to allow the propagation of the thermal damage front through the entire volume of hair and to damage follicular stem cells. This study also shows that the longer pulse width application produced better permanent hair removal results for the same number of treatments.

Adverse effects were documented in two subjects treated with HR. One complained of perifollicular hyperpigmentation and dropped out, whereas the other presented with hypopigmentation, which improved at the last follow-up. Crust formation, vesicles, paradoxical effects, scarring, and superficial burning, which are documented side effects of IPL photoepilation,[22] were not detected in the volunteers treated with HR over the 8-month follow-up after their last session. Pigmentary disturbances are troublesome but are common in those with a dark skin phenotype after laser and IPL treatment. However, no adverse outcome was observed in volunteers treated with HR-D over an 8-month follow-up period after the last session, although, in general, the axilla is a non–sun-exposed area and is associated with a lower risk of complication.

This study's limitation is that direct comparisons of applied fluences between each treated group are not reasonable because the applied pulse widths were different. The same applies to the clinical outcome. However, there were no statistically significant differences in demographic profiles and initial hair-growing status between each group and overall HRE was increased with application of longer wavelengths and pulse widths in the same IPL device. Therefore, the elimination of shorter wavelengths and the elongation of pulse duration appeared to allow more effective hair removal without significant side effects. It is important to note that this improvement is obtained on exactly the same equipment on the same type of patients treated on the same area. Careful selection of the band of wavelength and extended pulse duration for darker-skinned patients can increase the efficacy of hair removal by more than 80%. The filtered IPL source used was found to be a safer, more effective method of long-term permanent hair removal in darker-skinned Asian patients.

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