aaps

Archives of Aesthetic Plastic Surgery

A prospective, comparative evaluation of axillary hair removal with an 808-nm diode laser at different fluences

Hee Yong Kang, Eun Soo Park, Seung Min Nam

Department of Plastic and Reconstructive Surgery, Soonchunhyang University Bucheon Hospital, Bucheon, Korea

Background Diode lasers are the gold standard for removing unwanted hair. Lowering the energy should result in less pain and could theoretically affect therapeutic efficacy. This study evaluated the efficacy of an 808-nm diode laser at different fluences for permanent axillary hair removal in Korean women.

Methods Twenty-four Korean women were divided into two groups. Each patient received laser treatment at both axillae, which were divided into upper and lower parts. Each part received different fluence from an HR808 prototype diode at 1-month intervals: 8, 10, 12, and 14 J/cm^2. Hair count and thickness were recorded at each follow-up visit and at a 3-month follow-up after the final laser treatment by photography and using a folliscope. At the final visit, pain and patient satisfaction were surveyed. Three plastic surgeons assessed the results on photographs.

Results The mean hair follicle density reduction was 62.18%, 65.28%, 73.08%, and 78.29% on the right upper side, right lower side, left upper side, and left lower side, respectively. The mean hair follicle thickness reduction was 45%, 48%, 54%, and 59% on the right upper side, right lower side, left upper side, and left lower side, respectively. In the plastic surgeons' assessment, the left upper and lower sides scored 2.71. The right upper and lower sides scored 2.38 and 2.04, respectively.

Conclusions High-fluence (14 J/cm^2) treatment with an HR 808 prototype diode laser efficiently removed unwanted hair. No significant difference in comfort was reported compared to the low-fluence mode (8–10 J/cm^2).

Keywords Lasers, semiconductor / Hair removal / Laser therapy / Asian continental ancestry group

INTRODUCTION

The removal of unwanted body hair has recently become an increasingly prevalent trend, especially among women, and photo-epilation by laser or other light-based technology has become one of the most popular noninvasive procedures performed in dermatology and plastic surgery [1].

Current laser treatments are based on the mechanism of selective photothermolysis, in which laser energy heats the target, allowing the surrounding structures to remain relatively intact. In laser hair removal, melanin in the hair shaft acts as the target chromophore for targeting hair follicles. Energy is transferred to the associated stem cells and follicular bulb, while selective cooling of the epidermis minimizes epidermal injury and damage to epidermal melanin [2]. Various wavelengths have been proven to target melanin in many studies. Suitable laser and light sources include intense pulsed light sources, ruby lasers (694 nm), alexandrite lasers (755 nm), diode laser systems (800 nm), and long-pulse neodymium-doped yttrium aluminum garnet (Nd:YAG) lasers (1,064 nm) [3]. In the peer-reviewed literature, diode laser systems have emerged

as the most effective hair removal method [4].

In this study, we used an 808-nm diode laser. A previous study histologically demonstrated that repetitive low-fluence laser devices induced necrosis in hair follicles. The aim of this study was to conduct a comparative evaluation of forearm and lower leg hair removal using an 808-nm diode laser at different fluences.

METHODS

Patient selection

The study was retrospectively approved by the Institutional Review Board of Soonchunhyang University Bucheon Hospital (2015-04-013). This was a prospective single-center, bilaterally paired, randomized comparison study. Twenty-four female patients were enrolled at Department of Plastic and Reconstructive Surgery of Soon-

chunhyang University Bucheon Hospital from February 2017 through May 2018. Patients who met the eligibility criteria were enrolled in this study. The inclusion criteria were as follows: age between 25 and 48 years, ability to comply with all study requirements, and willingness to refrain from using any other hair removal treatments during the duration of the study. The exclusion criteria of this study were as follows: age under 25 years or above 48 years; any signs of active localized or systemic infections; history of herpes simplex virus or acne scarring in the treatment area; allergy or photosensitivity; use of photosensitizing medications, minoxidil, isotretinoin, finasteride, or steroids; skin pigmentation disorders, ichthyosis, vitiligo, or psoriasis; pregnancy or plans to become pregnant; tattoos, chronic daylight exposure, or tanning; and having received other laser hair removal treatment for the axilla (within 20 weeks).
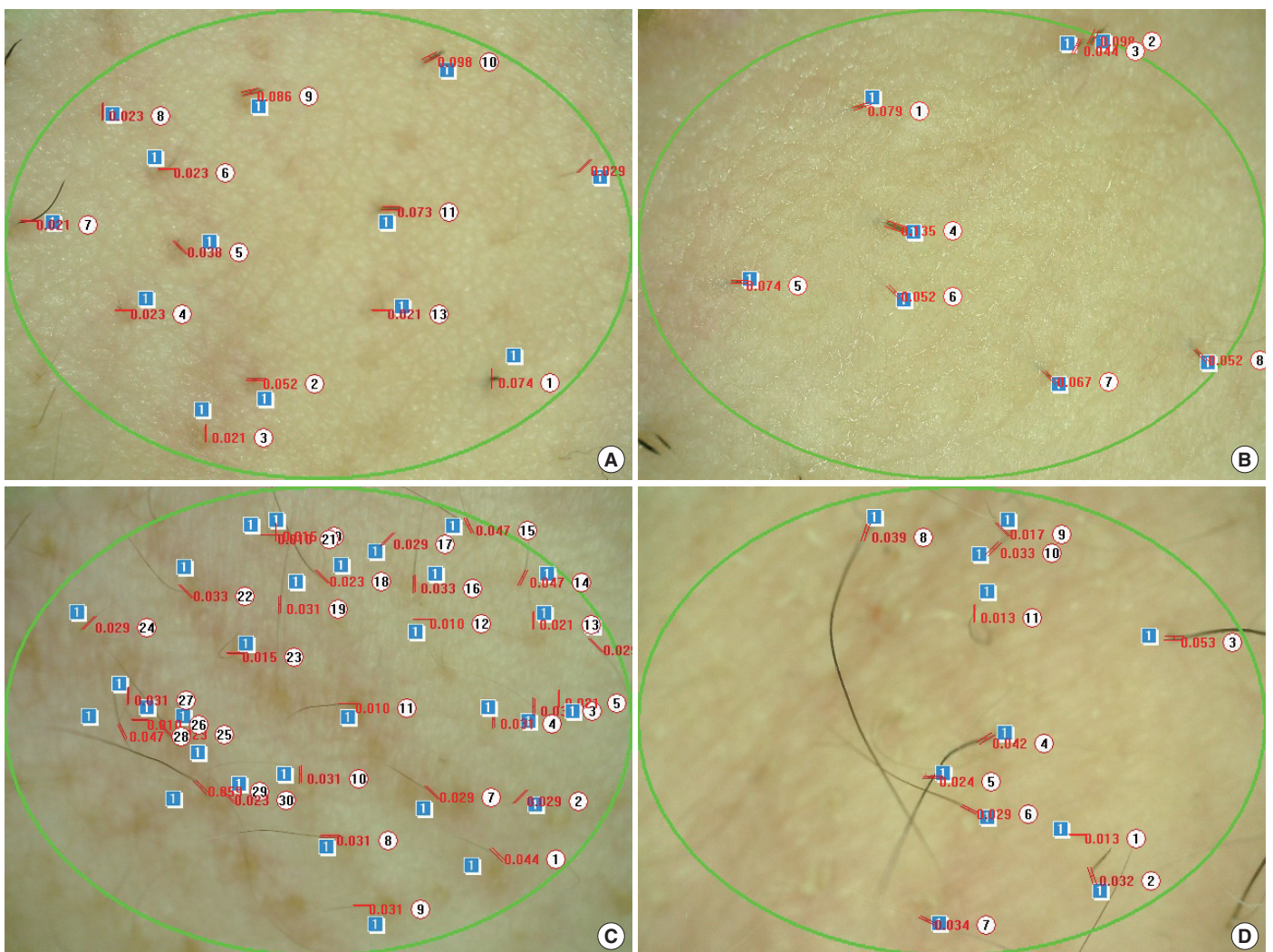

Fig. 1. Example of counting hair roots per square centimeter on the forearm in the axilla, before and after the fourth treatment, based on folliscope images. (A) Pretreatment folliscope findings of the right upper area. (B) Folliscope findings of the right upper area at fourth visit. (C) Pretreatment folliscope findings of the left lower area. (D) Folliscope findings of the left lower area at fourth visit.

Study procedure

At the first visit, the hair count per square centimeter and hair follicle thickness were estimated on both axillae to determine the baseline values before treatment, and the first treatment was performed. All patients then received three treatment sessions, with a gap of at least 1 month between each session. In general, hair removal laser treatment was done at intervals of 1 to 2 months, and we established a minimum interval of 1 month. In all patients, an area measuring 2.5×2.5 cm was used to determine the baseline hair density. The ratio of the number of hairs before and after laser treatment was calculated. We used an 808-nm diode laser system (HR808 prototype diode laser; Wontech, Daejeon, Korea) in this study. Before treatment, a water-based lubricating gel at an ambient temperature was applied for epidermal protection as a heat sink. Hair trimming was done to a uniform length of 1–2 mm using safety scissors. Both axillary areas were divided into upper and lower parts. Each part was treated with a different fluence: 8 J/cm^2 on the right upper part, 10 J/cm^2 on the right lower part, 12 J/cm^2 on the left upper part, and 14 J/cm^2 on the left lower part. Laser pulses were given with two to four passes and emitted at a fixed rate of 5 Hz. The exposure duration time was 40 milliseconds in all areas. The spot size of our instrument was 10×10 mm. The mean time interval between successive pulses was 1–2 seconds. The clinical endpoint of treatments was the presence of slight perifollicular erythema.

After each session, digital photographs (Nikon D750, Tokyo, Japan) were performed prior to the laser treatment in a photographic room. For each photo, identical ambient lighting, camera settings, and patient positioning were maintained. A standardized view with a fixed distance of 100 cm was used. Follicle thickness and density of the hair were assessed using a folliscope (Fig. 1). The results were evaluated 3 months after completion of the final treatment session.

The intensity of pain was subjectively expressed by each patient and recorded after each treatment. Pain was assessed using a visual analogue scale (VAS) for pain (0–10: 0, no pain; 10, worst possible pain). Therapeutic outcomes were assessed by patients' satisfaction with the treatment results, which was evaluated using the following 4-point grading scale. At the 3-month (visit 5) follow-up visit, all subjects rated their satisfaction as excellent (3), very good (2), good (1), or fair (0). Independent clinical assessments of the treatment

areas were conducted by three plastic surgeons who were blinded to the laser protocol based on comparative photographs using the following 5-point grading scale: 0, no change; 1, slight improvement ($\leq 25\%$); 2, moderate improvement (26%–50%); 3, significant improvement (51%–75%); 4, excellent improvement ($>75\%$). The final score of the physicians' assessment was determined by the median value of the three scores for each patient (Table 1).

Statistical analysis

SPSS version 14.0 (SPSS Inc., Chicago, IL, USA) was used for statistical analysis. Repeated-measures analysis of variance was performed to compare the changes in measured values over time among the four groups. P-values <0.05 were considered to indicate statistical significance.

RESULTS

The study population comprised 24 subjects who visited our clinic for axillary hair removal. Their average age was 32.8 years (range, 25–48 years). Based on a comparison of data from the first visit and the final visit (3 months after treatment completion), the mean hair follicle density reduction was 62.18%, 65.28%, 73.08%, and

Table 1. Results of plastic surgeons' assessments on a 5-point grading scale

Score	Evaluation
0	No change
1	Slight improvement (≤25% of hair is removed)
2	Moderately improvement (26%–50% of hair is removed)
3	Significant improvement (51%–75% of hair is removed)
4	Excellent improvement (>75% of hair is removed)

Table 2. Axillary hair follicle density

	Right upper	Right lower	Left upper	Left lower	P-value
Visit 0 (screening)	13.75±6.36	14.92±9.04	14.75±10.04	14.88±9.18	0.962
Visit 1	10.29±6.27	10.33±7.83	9.71±7.13	9.79±8.50	0.971
Visit 2	8.52±10.12	8.00±9.06	6.50±7.55	5.95±8.12	0.747
Visit 3	7.58±6.35	6.67±7.08	5.47±6.74	4.25±9.86	0.085
Visit 4	5.93±7.82	5.71±8.68	4.12±7.64	3.52±9.27	0.428
Visit 5	5.20±6.62	5.18±7.83	3.97±4.53	3.23±8.23	0.001
P-value	0.004	0.001	0.013	0.020	

Values are presented as mean±SD. All unit of dada is counts/cm².
P-values <0.05 were considered to indicate statistical significance.

Table 3. Axillary hair follicle thickness

	Right upper	Right lower	Left upper	Left lower	P-value
Visit 0 (screening)	0.058±0.02	0.059±0.02	0.058±0.02	0.06±0.02	0.816
Visit 1	0.054±0.02	0.054±0.02	0.053±0.02	0.053±0.02	0.809
Visit 2	0.051±0.02	0.05±0.02	0.051±0.02	0.05±0.01	0.571
Visit 3	0.049±0.02	0.047±0.02	0.045±0.02	0.041±0.01	0.502
Visit 4	0.038±0.01	0.035±0.02	0.031±0.02	0.031±0.01	0.234
Visit 5	0.032±0.01	0.031±0.01	0.027±0.01	0.025±0.01	0.833
P-value	<0.001	<0.001	<0.001	<0.001	

Values are presented as mean±SD. All unit of dada is μm.
P-values <0.05 were considered to indicate statistical significance.

78.29% on the right upper side, right lower side, left upper side, and left lower side, respectively (Table 2). The mean hair follicle thickness reduction was 45%, 48%, 54%, and 59% on the right upper side, right lower side, left upper side, and left lower side, respectively (Table 3). The density and thickness changes were statistically significant in each group, but there were no statistically significant intergroup differences ($P < 0.05$).

The VAS pain scores were 2.24, 2.29, 3.08, and 3.49 for the right upper side, right lower side, left upper side, and left lower side, respectively. The plastic surgeons' assessment scores were 2.71 for both the left upper and lower sides, 2.38 for the right upper side, and 2.04 for the right lower side.

Some patients reported a slight heating sensation during the treatments, but indicated that it was tolerable. After the treatments, perifollicular erythema occurred and disappeared within 10 hours. There were no side effects such as burn injury, rash-like lesions, skin atrophy, or changes of pigmentation (hypopigmentation or hyperpigmentation).

DISCUSSION

In the modern world, the growth of hair in anatomic areas that are not cosmetically desirable is a common aesthetic problem. The methods of removing unwanted body hair include shaving, plucking, waxing, and chemical epilation. However, these methods yield temporary results. Laser hair removal was introduced in 1996 by Grossman et al. [5], who reported that ruby lasers had a hair removal effect. Laser hair removal has subsequently proven to be a comfortable and effective method, as confirmed by many clinical studies in the literature [6-8].

Numerous clinical studies have reported that diode lasers provide a safe, fast, and comfortable platform that can be used to manipulate a wide range of fluences, making them suitable for use on hair throughout the body [9]. Diode and neodymium-doped yttrium aluminum garnet (Nd:YAG) lasers have few and transient side effects, such as hyperpigmentation and pain, with skin types III to V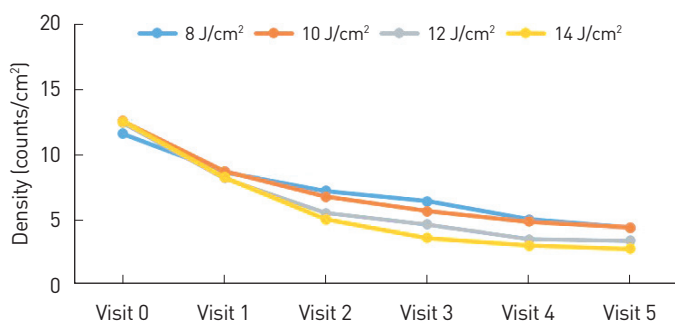 because epidermal melanin absorption is lower for long-wavelength lasers [4]. Several previous clinical trials have compared the efficacy of hair removal between diode and Nd:YAG lasers in patients with darker skin types. Li et al. [10] compared the efficacy of diode and Nd:YAG lasers for axillary hair removal in Chinese women, and found that after two sessions, the hair reduction rate of the diode laser system was 78.56%, whereas a reduction rate of 64.50% was observed for the Nd:YAG laser. Bouzari et al. [11] also studied the difference between Nd:YAG and diode lasers for hair removal on the face and neck. The mean hair reduction was 42.4% and 46.9% for Nd:YAG and diode lasers, respectively. Furthermore, the mean number of laser treatment sessions was 2.6 ± 1.2 for patients who underwent diode laser treatment, which was significantly lower than that of patients who underwent Nd:YAG laser treatment (5.5 ± 2.2 sessions). In terms of treatment comfort, Eremia and Newman [12] noted that lasers with longer wavelengths caused more pain than lasers with shorter wavelengths. Youn et al. [13] reported that in Koreans, the most common skin type was type III (48.8%), followed by type IV (22.2%) and type V (17.8%). Based on the abstract of [13] a tendency was also found for skin types IV and V to become more frequent with advancing age. Therefore, because few studies have reported the efficacy of diode laser treatment in Korean patients, we evaluated diode laser treatment in Korean women. For our instrument, the manufacturer's fluence guideline for the axillary area was over 8 J/cm². Therefore, to investigate the optimal treatment parameters, we utilized a range of fluence levels, starting at 8 J/cm² with slight increases.

Many studies have investigated the relationships of fluence and repetition rate with treatment effectiveness in diode laser treatment. Recent studies of diode lasers have suggested a shift away from the previously standard high-fluence devices in favor of a low-fluence (5–15 J/cm²) approach [14]. Braun [15] and Koo et al. [16] described a dramatic decrease in therapy-related pain and good efficacy after the use of low fluency 810-nm lasers with a high average power and a multiple-pass technique. Pai et al. [17] compared two 810-nm diode laser machines with different fluence levels and repetition rates for facial hair removal. They reported that a mode with low fluence (10 J/cm²) and a high repetition rate (10
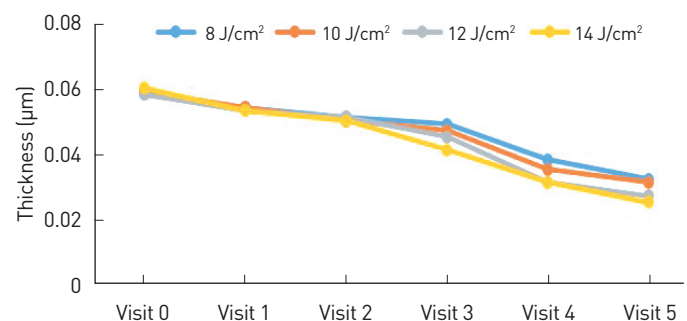

Fig. 2. Changes in the density of axillary hair. Data are shown as mean results.

Fig. 3. Changes in the thickness of axillary hair. Data are shown as mean results.

Hz) was more efficient and caused less pain than a mode combining high fluence (25–35 J/cm^2) with a low repetition rate (2 Hz). Li et al. [18] also compared different fluence levels and repetition rates of using an 810-nm diode laser for axillary hair removal in Chinese women. They reported that a low fluence (10 J/cm^2) and a high repetition rate (10 Hz) had greater efficacy and less treatment discomfort than a mode combining high fluence (34–38 J/cm^2) with a low repetition rate (1 Hz).

In our study, a different tendency was observed. For the objective parameters (hair density and follicle thickness), higher fluence was associated with higher overall mean reduction rates of density and follicle thickness (Figs. 2, 3). However, there was no statistically significant difference among the four groups. We think that our findings likely occurred as a result of the small number of enrolled patients and the smaller gap in the fluence parameter than in other studies.

The majority of patients were satisfied with their treatment, as 80% of patients provided a response of "excellent" or "very good" (Fig. 4). The same tendency was shown for higher levels of the fluence parameter to be associated with a higher rate of "excellent" responses (Fig. 5). In the visual assessment by plastic surgeons, the scores for the left side (12–14 J/cm^2) were higher than those of the right side. On the right side, the right upper side (10 J/cm^2) received a higher score than the right lower side (8 J/cm^2). The pain score was higher for the left side, but the difference between sides was slight.

In comparison with the findings of other studies, one of our noticeable results is that the parameter of "high" fluence was much lower than that of other comparative studies. Theoretically, lowering the fluence should reduce the pain resulting from the treat-

ment. The pain caused by laser treatment may be influenced by many factors, such as the laser parameters (fluence, wavelength, and pulse duration), treatment site, and skin cooling technique. Rogachefsky et al. [19] reported that pain was directly related to longer pulse duration and higher fluence, and that complications were most severe in patients treated with the highest pulse duration and fluence. However, in our study, the pain score of the high-fluence is similar to that of the low-fluence groups in other studies [17,19], and long-term complications were not investigated. Another difference is that we used a small number of pass technique, whereas the low fluence treatments in other studies used a multiple pass technique; a small number of pass technique was used in this study in order to reduce the time required for the treatment.

The axillary area is very sensitive to pain, and the patient must maintain an uncomfortable position during treatment in comparison with hair removal at other sites. Therefore, in addition to the effects of treatment, patients' satisfaction is important factor in promoting adherence to the treatment regimen. Therefore, we sug-
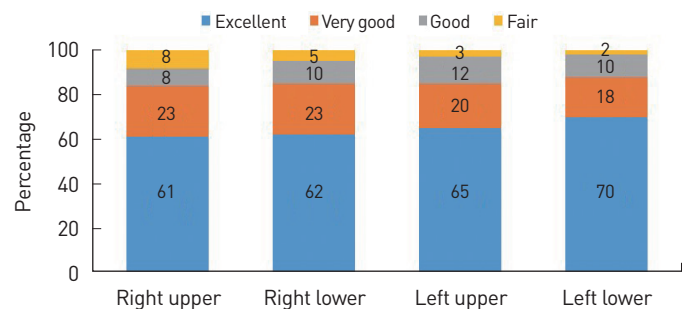

Fig. 5. Patient satisfaction.

Fig. 4. Representative photographs of a study subject's axilla at baseline and 3-month follow-up visits. (A) Pretreatment findings of the right axillary upper and lower areas. (B) Follow-up findings of the right axillary upper and lower areas. (C) Pretreatment findings of the left axillary upper and lower areas. (D) Follow-up findings of the left axillary upper and lower areas.

gest that the high level of fluence in our study (14 J/cm^2) is advantageous in terms of patients' comfort and adherence to treatment. We obtained a slightly better treatment effect than the conventional low-fluence treatment, while maintaining a similar level of comfort. Furthermore, our treatment time was shorter than that of the low-fluence treatments in other studies due to fewer number pass technique than other treatment regimen.

In conclusion, the high-fluence mode (14 J/cm^2) efficiently removed unwanted axillary hair. This mode also significantly reduced the treatment time compared to the low-fluence mode of the diode laser system, with similar comfort and higher patient satisfaction. Therefore, for axillary hair removal with a HR808 prototype diode laser, the high-fluence mode is better than the low-fluence mode. Further studies with more patients will be necessary to verify whether a statistically significant difference is present.

NOTES

ORCID
Hee Yong Kang   https://orcid.org/0000-0002-9902-0604
Eun Soo Park   https://orcid.org/0000-0003-2966-9122
Seung Min Nam   https://orcid.org/0000-0001-7865-5013

REFERENCES

1. Ibrahimi OA, Avram MM, Hanke CW, et al. Laser hair removal. Dermatol Ther 2011;24:94-107.
2. Yassin HF. Hair removal by using laser different. IOSR J Appl Phys 2019;4:9-13.
3. Casey AS, Goldberg D. Guidelines for laser hair removal. J Cosmet Laser Ther 2008;10:24-33.
4. Gan SD, Graber EM. Laser hair removal: a review. Dermatol Surg 2013;39:823-38.
5. Grossman MC, Dierickx C, Farinelli W, et al. Damage to hair follicles by normal-mode ruby laser pulses. J Am Acad Dermatol 1996;35:889-94.
6. Ilknur T, Bicak MU, Eker P, et al. Effects of the 810-nm diode laser on hair and on the biophysical properties of skin. J Cosmet Laser Ther 2010;12:269-75.
7. Wanitphakdeedecha R, Thanomkitti K, Sethabutra P, et al. A split axilla comparison study of axillary hair removal with low fluence high repetition rate 810 nm diode laser vs. high fluence low repetition rate 1064 nm Nd:YAG laser. J Eur Acad Dermatol Venereol 2012;26:1133-6.
8. Barolet D. Low fluence-high repetition rate diode laser hair removal 12-month evaluation: reducing pain and risks while keeping clinical efficacy. Lasers Surg Med 2012;44:277-81.
9. Agarwal M, Velaskar S, Gold MH. Efficacy of a low fluence, high repetition rate 810nm diode laser for permanent hair reduction in indian patients with skin types IV-VI. J Clin Aesthet Dermatol 2016;9:29-33.
10. Li R, Zhou Z, Gold MH. An efficacy comparison of hair removal utilizing a diode laser and an Nd:YAG laser system in Chinese women. J Cosmet Laser Ther 2010;12:213-7.
11. Bouzari N, Tabatabai H, Abbasi Z, et al. Laser hair removal: comparison of long-pulsed Nd:YAG, long-pulsed alexandrite, and long-pulsed diode lasers. Dermatol Surg 2004;30:498-502.
12. Eremia S, Newman N. Topical anesthesia for laser hair removal: comparison of spot sizes and 755 nm versus 800 nm wavelengths. Dermatol Surg 2000;26:667-9.
13. Youn JI, Choe YB, Park SB, et al. The Fitzpatrick skin type in Korean people. Korean J Dermato 2000;38:920-7.
14. Halachmi S, Lapidoth M. Low-fluence vs. standard fluence hair removal: a contralateral control non-inferiority study. J Cosmet Laser Ther 2012;14:2-6.
15. Braun M. Permanent laser hair removal with low fluence high repetition rate versus high fluence low repetition rate 810 nm diode laser: a split leg comparison study. J Drugs Dermatol 2009;8:s14-7.
16. Koo B, Ball K, Tremaine AM, et al. A comparison of two 810 diode lasers for hair removal: low fluence, multiple pass versus a high fluence, single pass technique. Lasers Surg Med 2014;46:270-4.
17. Pai GS, Bhat PS, Mallya H, et al. 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;13:134-7.
18. Li W, Liu C, Chen Z, et al. Safety and efficacy of low fluence, high repetition rate versus high fluence, low repetition rate 810-nm diode laser for axillary hair removal in Chinese women. J Cosmet Laser Ther 2016;18:393-6.
19. Rogachefsky AS, Silapunt S, Goldberg DJ. Evaluation of a new superlong-pulsed 810 nm diode laser for the removal of unwanted hair: the concept of thermal damage time. Dermatol Surg 2002;28:410-4.