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ORIGINAL RESEARCH REPORT

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

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ABSTRACT

Background: High-fluence diode lasers with contact cooling have emerged as the gold standard to remove unwanted hair. Lowering the energy should result in less pain and could theoretically affect the efficacy of the therapy. **Objective:** To compare the safety and efficacy of a low fluence high repetition rate 810-nm diode laser to those of a high fluence, low repetition rate diode laser for permanent axillary hair removal in Chinese women. **Methods:** Ninety-two Chinese women received four axillae laser hair removal treatments at 4-week intervals using the low fluence, high repetition rate 810-nm diode laser in super hair removal (SHR) mode on one side and the high fluence, low repetition rate diode laser in hair removal (HR) mode on the other side. Hair counts were done at each follow-up visit and 6-month follow-up after the final laser treatment using a "Hi Quality Hair Analysis Program System"; the immediate pain score after each treatment session was recorded by a visual analog scale. **Results:** The overall median reduction of hair was 90.2% with the 810-nm diode laser in SHR mode and 87% with the same laser in HR mode at 6-month follow-up. The median pain scores in SHR mode and in HR mode were 2.75 and 6.75, respectively. **Conclusion:** Low fluence, high repetition rate diode laser can efficiently remove unwanted hair but also significantly improve tolerability and reduce adverse events during the course of treatment.

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China; diode laser; hair removal; high fluence single pass; low fluence multiple pass

Introduction

Laser hair removal technologies are proven to be successful methods for permanent hair removal and have become one of the most common noninvasive cosmetic procedures performed in dermatology and plastic surgery. Commonly used lasers and light sources for epilation include ruby laser (694 nm), alexandrite laser (755 nm), diode laser systems (810 nm), long-pulsed Nd:YAG laser (1064 nm), as well as the intense pulsed light (IPL) source and variants of the IPL, such as electro-optical synergy technology. In the peer-reviewed literature, the diode laser systems have emerged as the most effective hair removal method (1,2). Diode laser systems for hair removal have traditionally used a long pulse width with high energy densities. However, the high-energy laser can potentially increase the risk of skin burns during the course of treatment and many patients have also suffered pain due to insufficient cooling during the treatment. Lowering the energy should result in less pain and fewer potential adverse events, but this could theoretically affect the efficacy of the therapy.

The purpose of this study is to investigate the safety and efficacy of a new diode laser, the Soprano® XL laser in super hair removal (SHR) mode (LFMP, low fluence multiple pass) compared to HR mode (traditional HFSP, high fluence single pass) for axillae hair removal in Chinese women.

Materials and methods

Clinical data

Subjects. Ninety-six female volunteers were recruited from the hospital staff and the outpatient clinics of the Department of Dermatology of Peking University People's Hospital in Beijing, China from April 2010 through June 2014. These women were between the ages 18 and 41 years with a mean age of 26.2 ± 4.21 years. The subjects in the clinical trial had Fitzpatrick skin types III–V, and all treated hair was noted to be dark terminal hairs. Exclusion criteria utilized in this clinical trial included the following: having received any laser or electrolysis for axillary hair removal; waxing, shaving, or removing axillary hair in any other fashion for the month prior to the beginning of the study; any signs or symptoms of a bacterial, viral, or fungal infection noted in the treatment areas; women who were pregnant or planning to become pregnant during the course of the clinical trial; a history of keloid formation; a history or laboratory finding of any abnormal sex hormone levels; ingestion of vitamin A acid drugs or derivatives; and a history of light sensitivity in the skin.

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Table 1. Diode laser system specifications.

	SHR mode	HR mode
Wavelength	810 nm	810 nm
Repetition rate	10 Hz	1 Hz
Spot size	9 mm(square)	9 mm(square)
Fluence	10 J/cm^2	34–38 J/cm^2
Pulse duration	30 ms	30 ms

Methods

This is a prospective single-center, bilaterally paired-, blinded-, randomized-comparison study. All patients were randomized to receive hair removal treatments with 810-nm diode laser (Soprano® XL) in SHR mode or in HR mode on either the left axillae or the right axillae in a random order. Conventional preparation for laser hair removal was done before each treatment session, including shaving of hair in a 1-mm-long area, cleansing, and disinfection of the treatment area. The axilla to be treated was coated with 2–3-mm-thick cold gel. A test spot was performed prior to the actual treatment. The reasonable test spot response was minor acceptable pain or thermal warmth during the treatment with slight follicular erythema or slight perifollicular edema. The specific parameters used during the treatments are listed in Table 1. Each axilla was treated four times at 4-week intervals. The first three follow-up visits were scheduled prior to the next treatment. The last follow-up was at least six months after the final laser treatment session. At each follow-up visit, any adverse event, including pigment changes, skin texture changes, or scar formation, was noted.

Hair reduction: For hair removal, a round area of 3.5 cm in diameter was chosen from the treatment site, which were marked and photographed. The same site was utilized during each treatment session to determine the hair removal rate in this study. Hair reduction was quantified utilizing the following formula: (the hair quantity before the first laser treatment – the hair quantity after the current laser treatment)/the hair quantity before the first laser treatment.

Immediate pain score: Patients were asked to score the degree of immediate pain using a visual analog scale (VAS), with 0 being the score for no pain, and 10 being the score for intolerable pain. The patients were asked to mark the score accordingly on the VAS form.

Wilcoxon signed-rank test was used as a statistical analysis tool.

Results

A total of 92 female patients above the age of 18 years completed the study. Four additional patients were enrolled, but they did not finish the protocol and were excluded from the results. All the data were analyzed using appropriate statistical tests at the end of 4 sessions of treatment. Statistical significance was considered to be $p < 0.05$. Based on hair density recorded at the beginning and the end of the treatment session, we found that the overall median reduction of hair was 90.2% with the 810-nm diode laser in SHR mode and 87% in HR mode (Table 2). Comparing the hair removal percentages between these two lasers using the Wilcoxon signed-rank test, we found that these differences were not statistically significant ($p = 0.803$).

We observed that the median pain scores of the 810-nm diode laser in SHR mode and in HR mode were 2.75 and 6.75, respectively (Table 2), as measured on a 0–10 visual analog scale (0 = no pain and 10 = unbearable pain) over the four treatment sessions. The difference of overall pain scores was statistically significant ($p = 0.0005$).

Hair reduction rate

The mean hair reduction rates with the diode laser in SHR mode side and in the HR mode side were 42.8 ± 15.8 and 40.2 ± 18.3% after the first laser treatment, 62.2 ± 11.3 and 65.5 ± 10.4% after two treatment sessions, and 86.3 ± 12.2 and 82.6 ± 15.2% after three treatment sessions, respectively. At the 6-month follow-up visit after the final laser treatment, the mean hair reduction rates on the diode laser in SHR mode side and on the HR mode side were 90.2 ± 11.2% and 87.0 ± 13.3%, respectively (Figure 1). There was no statistical difference in efficacy between two groups ($p = 0.803$) in hair reduction rates (Table 2).

Pain assessment during treatment

The pain assessment during treatment is shown in Table 2. In the first treatment session, the means and standard deviation of immediate pain scores on the VAS scale were 3.3 ± 1.2 and 7.6 ± 1.6 for the diode laser in SHR mode and in HR mode, respectively. The corresponding VAS scores were 3.1 ± 1.5 and 7.0 ± 1.3 at the second session, 2.6 ± 1.3 and 6.3 ± 1.7 at the third session, and 2.0 ± 1.1 and 6.1 ± 1.2 at the final treatment. All results were statistically significant. Overall, the patients felt that the treatment in HR mode was more painful than the SHR mode.

Adverse reactions

Two subjects, who received diode laser hair removal in HR mode, experienced pigmentation changes during the course of this clinical trial. They experienced postinflammatory hyperpigmentation (PIH) and had Fitzpatrick skin type V with "bushy" hair. The PIH resolved in all of these subjects at

Table 2. Results of hair reduction and pain.

	SHR mode				HR mode			
	F–1	F–2	F–3	F–4	F–1	F–2	F–3	F–4
Hair reduction(%)	42.8 ± 15.8	62.2 ± 11.3	86.3 ± 12.2	90.2 ± 11.2	40.2 ± 18.3	65.5 ± 10.4	82.6 ± 15.2	87.0 ± 13.3
Pain	3.3 ± 1.2	3.1 ± 1.5	2.6 ± 1.3	2.0 ± 1.1	7.6 ± 1.6	7.0 ± 1.3	6.3 ± 1.7	6.1 ± 1.2

F–1: Follow-up 1; F–2: Follow-up 2; F–3: Follow-up 3; F–4: Follow-up 4.

Figure 1. Representative photographs of a study subject's axilla at baseline and 6-month follow-up visits.

the final visit without any special treatment. No other adverse reactions were noted during the course of this study, including blister or purpura formation, skin texture changes, or scarring in either of the treatment methods.

Discussion

High-fluence diode lasers with contact cooling have been the gold standard to remove unwanted hair. Studies have shown that the percentage of hair loss is fluence-dependent, with a higher percentage of hair loss at a higher fluence (3–6). However, laser hair removal can be painful, and result in hypopigmentation or postinflammatory hyperpigmentation, especially in dark skin tones (7). In our study, we compared the safety and efficacy of a low fluence, high repetition rate 810-nm diode laser to those of a high fluence, low repetition rate diode laser for permanent axillary hair removal in Chinese women. We found that the overall mean hair reduction rates were similar with the diode laser in SHR mode and in HR mode, but the median pain scores of hair removal in SHR mode was lower than that of HR mode.

A novel low fluence, high repetition rate 810-nm diode laser using multiple passes has been recently introduced as an option of laser hair removal with less treatment discomfort and fewer side effects when compared with traditional laser hair removal (8). Unlike standard HFSP diode laser devices, the low-fluence diode laser incorporates a high-pulse repetition rate and a constant motion technique. In such light spots, the maximum fluence of LFMP is only 10 J/cm^2 while the fluence of HFSP is more than 30 J/cm^2. Theoretically, lowering the fluence is supposed to reduce pain due to the procedure and potential side effects; however, it can affect the therapeutic efficacy. In Braun's study, 25 patients were randomly treated with multiple passes, low fluence (5–10 J/cm^2), high repetition rate (10 Hz) and single-pass, high-fluence (25–40 J/cm^2) 810-nm diode laser. The author found that the efficacy of these two methods at 6-month follow-up after five treatments were comparable at 86–91% hair reduction (8). Our result also supports Braun's study findings. At 6-month follow-up after four section of laser treatment, the mean hair reduction rates were similar with the diode laser in SHR mode and in HR mode ($90.2 \pm 11.2\%$ vs. 87.0 ± 13.3, $p = 0.803$). The mechanism behind this is that the high repetition rate can compensate the efficiency loss of using low-fluence laser. The use of repeated low-fluence pulses over a single area leads to cumulative dermal heating due to heat transfer from the laser-heated hair to the perifollicular dermis. After repeated short low-fluence pulses, the accumulated heat in the perifollicular tissue is maintained for a longer time, resulting in damage

to the follicle and durable hair reduction. Therefore, compared to traditional, high-fluence laser epilation, this approach has reduced pain and a lower risk of burns and adverse events. Effective thermal induction to hair follicles occurs, with cytopathic changes and also vacuole formation at the basal layer as noticed in histologies (9,10). Recent studies also confirmed that LFMP diode laser treatment was as effective as HFSP diode laser or HFSP IPL treatment for permanent hair removal (11–14).

Although some variance was observed when using low fluence, high repetition rate laser in different patient populations, all the studies have showed reduced pain level and improved tolerability during the course of treatment. The pain generated from the procedure may be influenced by many factors, such as the laser parameters (wavelength, pulse duration, and fluence), the quantity and quality of hair, skin color, and skin cooling. Rogachefsky et al. have shown that the pain was directly related to higher fluencies and longer pulse duration, and that pain and complications were greatest at the highest pulse duration and fluence (15). The conventional HFSP diode laser releases very high fluence in a single, very short pulse, leading to a sharp rise in the temperature of follicle and epidermis and causes more obvious pain. However, the energy of the LFMP laser, repeatedly released at lower fluence, gradually and slowly heats up the follicle and epidermis and causes less obvious pain. The Soprano XL focused on raising the temperature of the subdermal layer of the skin progressively to at least 45° C, and up to the thermal destruction temperature of the hair follicle without heating the epidermis of the skin region. The approach of using low fluence with repetitive millisecond pulses to achieve heat stacking in the hair bulb and bulge represents a paradigm shift in laser hair removal methodology. With the high-speed pulse repetition of the laser used in SHR mode, epilation is done with the continuous movement of the handpiece over the skin. The epidermis remains cooler than the dermis and hair follicle throughout treatment by combining with the constant cooling by the chilled contact tip. By delivering laser pulses in motion, energy is prevented from concentrating on a single point, and thus, burning is avoided and pain is not obvious. Our study approved that a low fluence, high repetition rate 810-nm diode laser has a potential to become an efficient method of laser hair removal with less treatment discomfort and fewer side effects.

Conclusions

Low fluence with high repetition rate 810-nm diode laser can not only efficiently remove unwanted hair, but also significantly improve tolerability and reduce adverse events when compared to traditional high-fluence diode laser.

Declaration of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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