

# Long-Term Efficacy of Linear-Scanning 808 nm Diode Laser for Hair Removal Compared to a Scanned Alexandrite Laser

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**Background and Objective:** Alexandrite and diode lasers are commonly used for hair removal. To date, the available spot sizes and repetition rates are defining factors in terms of penetration depth, treatment speed, and efficacy. Still, larger treatment areas and faster systems are desirable. To compare the efficacy, tolerability, and subject satisfaction of a continuously linear-scanning 808 nm diode laser with an alexandrite 755 nm laser for axillary hair removal.

**Study Design:** A total of 31 adults with skin types I–IV received 6 treatments at 4-week intervals with a 755 nm alexandrite laser (right axilla) and a continuously linear-scanning 808 nm diode laser (left axilla). Axillary hair density was assessed using a computerized hair detection system.

**Results:** There was a significant reduction in axillary hair after the 6th treatment ( $P < 0.05$ ) on both sides (left, 808 nm: hair clearance of 72.16%; right, 755 nm: hair clearance of 71.30%). The difference in reduction between the two lasers was not significant, but both were persistent at 18 months follow-up (left: hair clearance of 73.71%; right: hair clearance of 71.90%). Erythema and perifollicular edema were more common after alexandrite laser treatment, but all side effects were transient. While 62.50% of patients reported more pain in response to treatment with the new diode laser, all patients rated treatment with either laser tolerable.

**Conclusion:** Treatment with either the alexandrite or the linear-scanning diode laser results in significant, comparable, persistent (at least 18 months) axillary hair reduction among individuals with skin types I–IV. *Lasers Surg. Med.* © 2013 Wiley Periodicals, Inc.

**Key words:** laser; hair removal; selective photothermolysis; 808 nm; 755 nm

## INTRODUCTION

Laser hair removal is one of the most often used cosmetic procedures [1]. The efficacy of certain laser systems to destroy hair follicles within the skin is based on the theory of selective photothermolysis and its further development [2,3]. This concept aims for the permanent elimina-

tion of the dermal papilla and/or the stem cells within the bulge region. Terminal hair follicles are selectively damaged if a wavelength absorbed by melanin is applied to heat the structure. Although a number of wavelengths are available and long-lasting removal of hair was observed years ago, the procedure and systems are still being improved [4]. Notably, efficacy and side effects are major factors with room for improvement. In terms of efficacy and safety, the alexandrite laser and the long-pulsed diode laser (LPDL) are the most popular systems available and suitable for skin types I–IV.

A number of comparative studies have been conducted to ascertain which of the medium-wavelength lasers, namely the alexandrite and diode, is most effective and safe, but their results have been conflicting. Indeed, while a number of authors have found equivocal efficacy [5–7], support for the superiority of the alexandrite laser [8] and, conversely, for the diode laser [7] has also been reported. Part of this discrepancy can be explained by a short follow-up period ( $\leq 6$  months) for all but one of these studies [6]. Indeed, a proper assessment of the efficacy of any laser hair removal technique requires that test sites be followed up for at least the length of one complete hair cycle: a minimum of 6–9 months depending on the anatomical site studied [9]. Additionally, although current

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guidelines suggest up to eight treatments for optimal results [10], prior studies comparing the efficacy of alexandrite versus diode lasers tested the effects of only three to four treatments [5,8,6,11].

In addition to those study limitations, systems often suffer from small spot sizes, making hair removal procedures in larger areas, such as the back or both legs, impractical, time-consuming and inconvenient to physicians and patients. On top of this, a small spot size prevents deeper penetration and is related to the need for higher fluences due to scattering of photons [12]. Technical solutions to increase the spot size are being developed. Commonly, scanners are used to address larger areas by treating spots individually, sometimes in a random fashion. The major limitation of those systems is the speed of treatment due to a limited repetition rate.

A new technical solution to increase the spot size of LPDLs is linear scanning. While the actual laser beam is formed by a linear array of approximately  $1\text{ mm} \times 12\text{ mm}$ , a scanning device moves the beam in a linear fashion to a final spot size up to  $12\text{ mm} \times 50\text{ mm}$ . The speed of the scanner gives the appropriate pulse duration. Addressing the skin with a calculated pulse duration typical of LPDLs, the system allows for significantly faster treatment of a given skin area. Numerical simulations have been performed at the Institute for Laser Medicine (Ulm, Germany) to investigate the distribution of light and the corresponding heating in a human skin model.

Here, we report the long-term hair-removal efficacy of a linear-scanning 808 nm diode laser with an 18-month follow-up period. To overcome the lack of system comparability, we compared the efficacy and safety of six treatments with the new linear-scanning LPDL versus a conventional-scanning alexandrite laser for removing axillary hair.

## MATERIALS AND METHODS

A prospective, single-center, self-controlled study was designed to evaluate the long-term efficacy and safety of a newly developed linear-scanning diode laser (808 nm) system (Leda Epi, Alma Lasers GmbH, Erlangen, Germany) in comparison to a standard alexandrite 755 nm scanning hair removal laser (Arion, EpiCon Study, Alma Lasers GmbH, Erlangen, Germany). The study protocol was approved by the local review board committee (020–2008). In addition, the study protocol conformed to the ethical guidelines of the 1975 Declaration of Helsinki as reflected in approval by the institution's human research review committee.

### Histological Analysis of Laser-Tissue Interaction of Both Laser Systems

Prior to the clinical study, basic histological investigations were performed in human skin explants ( $n = 5$ ) after a single shot with the linear-scanning 808 nm diode laser (fluence:  $30\text{ J/cm}^2$ ; pulse duration: 12 millisecond) well as a single shot

with the 755 nm alexandrite laser ( $30\text{ J/cm}^2$ , 40 millisecond). The treated specimens were subjected to buffered 4% formalin for 24 hours for fixation. Tissue blocks were embedded in paraffin, cut into  $5\text{--}8\text{ }\mu\text{m}$  slices and stained with hematoxylin and eosin (H&E) according to standard procedures. Biopsies were evaluated under a calibrated microscope (BX41, Olympus Germany, Hamburg, Germany) equipped with a digital camera (DP70, Olympus Germany). Lesion dimensions were measured using calibrated CellF software (Olympus Germany). The samples were evaluated by two blinded dermatopathologists.

### Patients

Twenty-eight adult women (mean age  $31.2 \pm 9.3$  years) and three adult men (mean age  $30.3 \pm 4.9$  years) with a Fitzpatrick skin types I–IV with light- to dark-brown axillary hair were selected to participate in the study. Exclusion criteria for this study included prior axillary laser hair removal or other methods of epilation within 12 weeks of study entry, history of skin pigmentation disorders, hypersensitivity to UV light, chronic sun exposure or tanning, active cutaneous infection or other skin diseases within the treatment area, lack of compliance, and use of medications with androgenic effects or the ability to trigger susceptibility to light. Additionally, women who were pregnant or lactating were excluded. All patients provided written consent to participate in the trial and undergo axillary hair removal with two different laser systems.

### Laser Systems

The ARION single-spot scan alexandrite laser (Alma Lasers GmbH [former Wavelight Aesthetic GmbH followed by Quantel-Derma], Erlangen, Germany) has a wavelength of 755 nm, with adjustable pulse duration of 5 to 140 millisecond, fluence of up to  $100\text{ J/cm}^2$ , and spot size of  $6\text{ mm} \times 6\text{ mm}$  to  $16\text{ mm} \times 16\text{ mm}$ . To prevent epidermal damage, an air-cooling system (Zimmer MedizinSysteme GmbH, Cryo6, Neu-Ulm, Germany) has been attached directly to the hand piece and set to level 5. The system is equipped with a scanner (Energist Ltd, Swansea, South Wales, UK) enabling the operator to treat larger areas by placing pulses in a pseudo-random fashion.

The LEDA EPI continuous-scan diode laser (Alma Lasers GmbH) has a wavelength of 808 nm, with adjustable pulse duration of 6 to 60 millisecond, fluence of up to  $60\text{ J/cm}^2$ , and two scanned areas ("spot sizes"):  $50\text{ mm} \times 12\text{ mm}$  and  $10\text{ mm} \times 12\text{ mm}$ .

The laser beam itself is made of a rectangular array of diodes forming a spot of  $1\text{ mm} \times 12\text{ mm}$ . Using a mirror system this rectangular spot is moved linearly to cover an area of  $12\text{ mm} \times 50\text{ mm}$ . Scattering of the light along the 10 mm side of the rectangular spot allows a deep penetration in one dimension. At the 1 mm side, the scattering is also present within the second dimension, since the spot is moved continuously over the skin. Each area is therefore pre-heated by scattered photons, and immediately after this, the full beam is heating up the whole area.

Additionally, a cold air (Zimmer MedizinSysteme GmbH, Cryo6) or contact cooling system (ThermoTek, Inc., Flower Mound, TX) can be used during treatment. During the study the Zimmer cooler was set to level 5.

### Treatment Protocol

All study subjects were instructed to shave their axillae the day before each laser treatment. Each patient received a total of six treatments at 4-week intervals. During each treatment session, the right axilla was treated once with the 755 nm alexandrite laser using the scanner with a fluence of 25–30 J/cm<sup>2</sup>, a pulse duration of 30–40 millisecond, and a spot size of 10 mm, while the left axilla was treated with the 808 nm linear-scanning diode laser using a fluence of 24–30 J/cm<sup>2</sup>, a pulse duration of 12 millisecond, and a spot size of 50 mm × 12 mm. The progression of laser fluences and pulse durations during the six treatments is shown in Table 1. The 12 millisecond with the diode were selected to use the advantage of linear scanning, hence *in-vitro* simulation revealed that sufficient heat for hair removal is applied. No topical or local anesthesia was administered along with the laser treatment. To reduce side effects and patient discomfort, an air-cooling system was used during treatment with each laser at level 5. All laser treatments were performed by a board-certified dermatologist. After treatment, the subjects were instructed to cool the treated areas on demand with cooling packs.

### Clinical Assessments

Axillary hair density was assessed at baseline, before each treatment and at each follow-up visit using the automatic TrichoScan<sup>®</sup> (FotoFinder Systems GmbH, Bad Birnbach, Germany) analysis according to the manufacturer's instructions. TrichoScan<sup>®</sup> is a reliable and validated software program for quantifying hair growth that uses epiluminescence microscopy (FotoFinder, FotoFinder Systems GmbH, Bad Birnbach, Germany) with automatic digital image analysis. Indeed, the intra- and interclass reliability for TrichoScan<sup>®</sup> in the assessment of hair thickness as well as hair density is over 90% [13]. The video

camera of the FotoFinder system was used to capture images of the axillae with 20-fold magnification, allowing for analysis of an area of 0.651 cm<sup>2</sup>. The images were then loaded onto a computer, and the TrichoScan<sup>®</sup> software was used to analyze hair density (n/cm<sup>2</sup>). Pain, perifollicular edema, and erythema were quantified by the physician using visual analog scales [1–9]. Patients were followed up for long-term assessments at 6 and 18 months after the final treatment session.

### Patient Assessment

The perception of unwanted hair growth, pain, perifollicular edema, erythema, itch, crusting, and scarring were recorded by the study subjects 1 hour, 1 day, and 3 days post-treatment using visual analog scales on a questionnaire. Moreover, the pain level during the treatment was evaluated. Within the questionnaire, subjects further evaluated criteria like the level of subjective impairment of the hair growth, satisfaction with the treatment results, desire for further treatments and willingness to recommend it to a friend. Patient assessments were repeated at the follow-up visits 6 and 18 months after the final treatment session.

### Statistical Analysis

The hair densities of the right (alexandrite laser-treated) and the left (linear-scanning diode laser-treated) axillae were compared using the non-parametric Wilcoxon test. Changes in hair density from baseline were assessed using ANOVA. The rates of adverse effects and pain were compared between the alexandrite- and diode-treated axillae using the *t*-test for independent samples (groups). All statistical analyses were performed using Statistica 7.0 (Statsoft, Hamburg, Germany). A *P* value of <0.05 was considered statistically significant.

## RESULTS

The EpiCon Study was conducted from 2/2008–3/2011. Overall, 32 patients were included, and 31 completed all 6 study treatments; 1 patient was lost due to loss of contact.

At the 6-month follow-up visit 11 patients and at the 18-month follow-up visit 10 patients were available for evaluation. All patients were Caucasian with skin types I, II, III, and IV (6.25%, 53.12%, 34.37%, and 6.25%, respectively). Treatment areas of all study subjects were both axillae with no randomization of the laser system applied. Hair color was light to dark brown. A total of 64 axilla, 368 treatment sessions and 21 follow-up visits were conducted during the study period.

### Microscopic Changes

The microscopic investigation revealed no damage to the epidermal compartment, even within the follicular surroundings for both laser systems in all samples. Next to undamaged intact follicles at a dermal level, the 808 nm linear-scanning laser showed a strong thermal impact on the hair shaft, as well as at the dermal papilla (Fig. 1) as known from and found for alexandrite lasers.

**TABLE 1. Treatment Parameters**

Session number	755 nm alexandrite laser (right axilla)		808 nm diode laser (left axilla)	
	Fluence (J/cm <sup>2</sup> )	Pulse duration (millisecond)	Fluence (J/cm <sup>2</sup> )	Pulse duration (millisecond)
1	25	30	24	12
2	30	40	27	12
3	30	40	30	12
4	30	40	30	12
5	30	40	30	12
6	30	40	30	12

### Efficacy in Hair Reduction

Overall, both systems showed a high efficacy, with no worsening of the symptoms (e.g., paradoxical hair growth). The average hair densities of the right and left axillae of all 31 patients at baseline, before each of the 6 treatment sessions, and at 6 and 18 months after the 6th treatment session are presented in Table 2 and Fig. 2.

Average hair densities of the alexandrite laser-treated and diode laser-treated axillae were similar at baseline ( $30.91 \pm 9.90$  vs.  $30.82 \pm 10.11$  hairs per  $\text{cm}^2$ ;  $P > 0.05$ ). The hair densities decreased with each subsequent treatment session, with no statistically significant difference between both laser systems at any time point (Table 3).

Compared to baseline, there was a significant reduction in axillary hair after the 6th treatment (ANOVA,  $P < 0.05$ ) on both sites (left axilla, 808 nm: reduction to 27.84% [hair clearance of 72.16%]; right axilla, 755 nm: reduction to 28.70% [hair clearance of 71.30%]). Interestingly, the highest removal rate was achieved after the 1st laser treatment on both sites (left axilla, 808 nm:  $-35.69\%$  ( $P < 0.001$ ); right axilla, 755 nm:  $-36.36\%$  ( $P < 0.001$ )). During the ongoing treatment course, there was a similar, continuous decrease of hair density at both sites ( $P > 0.05$ ).

However, in both laser epilation protocols, a partial recovery of hair growth at the 6-month follow-up visit was observed. At this time, hair clearance rates significantly dropped from  $-72.16\%$  to  $-55.45\%$  (left axillae, 808 nm diode laser) and from  $-71.30\%$  to  $-52.05\%$  (right axillae, 755 nm alexandrite laser). Compared to the measurements at the time of the 6th treatment, this result reflects an approximate doubling in hair density.

Interestingly, the partial recovery of hair growth measured at the 6-month follow-up visit was only temporary on both sides. The overall hair clearance at 18 months was as follows: left axilla (808 nm): reduction to  $8.10 \pm 7.22$  hairs/ $\text{cm}^2$  [hair clearance of 73.71%]; right axilla (755 nm): reduction to  $8.70 \pm 8.54$  hairs/ $\text{cm}^2$  [hair clearance of 71.90%]. Both values are comparable to the hair reduction measured at the last treatment session (6th visit vs. 18-month follow-up:  $P > 0.05$ ), and consistent with the rest of the study course, there was no significant difference

**TABLE 2. Density of Axillary Hair [hairs/ $\text{cm}^2$ ]. Values are given as the Mean  $\pm$  Standard Deviation**

Time point	N	Left axilla (LEDA)	Right axilla (alexandrite)
Baseline	32	$30.82 \pm 10.11$	$30.91 \pm 9.90$
Pre-2nd treatment	31	$19.82 \pm 8.91$	$19.67 \pm 8.41$
Pre-3rd treatment	32	$16.66 \pm 11.40$	$17.86 \pm 10.44$
Pre-4th treatment	29	$15.20 \pm 6.43$	$14.19 \pm 6.55$
Pre-5th treatment	29	$14.25 \pm 8.90$	$14.51 \pm 11.87$
Pre-6th treatment	31	$8.58 \pm 5.52$	$8.87 \pm 6.45$
6-month follow-up	11	$17.09 \pm 10.44$	$16.09 \pm 13.55$
18-month follow-up	10	$8.10 \pm 7.22$	$8.70 \pm 8.54$

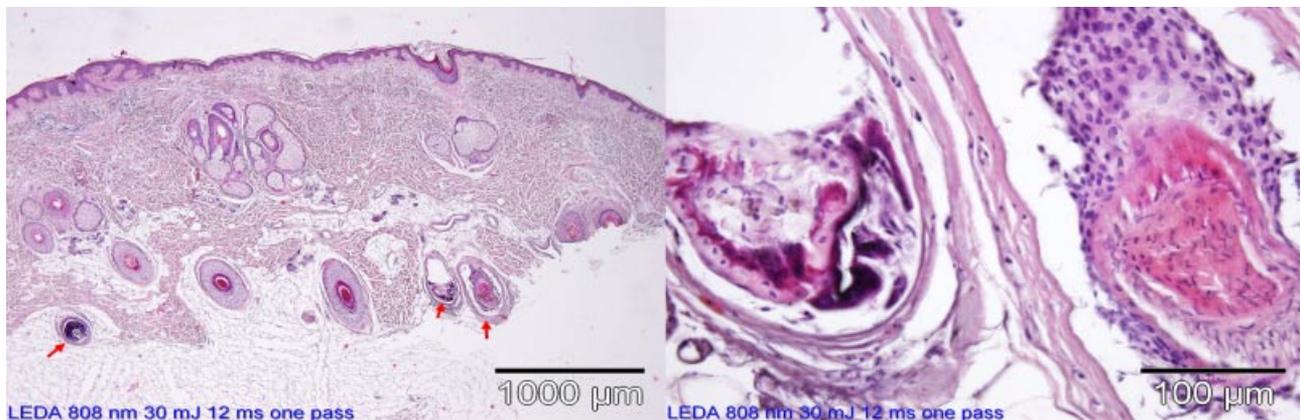
observed between both laser systems at 18 months ( $P > 0.05$ ).

Although the patients rated the hair clearance between baseline and the 6th treatment, the 6-month follow-up and the 18-month follow-up as significant, they were not aware of the transient decrease in hair clearance (level at 6th treatment vs. 6-month follow-up:  $P > 0.05$ ; level at 6-month follow-up vs. 18-month follow-up:  $P > 0.05$ ).

### Pain, Tolerability, and Treatment Time

The patients' evaluation of treatment-related pain using a visual analog scale (0, no pain; 10, intolerable pain) did not vary significantly during the course of the treatments ( $P > 0.05$ ). However, overall, the linear-scanning diode laser was rated to be slightly more painful ( $5.24 \pm 2.58$ ) compared with the alexandrite laser ( $4.39 \pm 2.44$ ,  $P > 0.05$ ). On the other hand, treatment duration with the linear-scanning diode laser system was only 21.6% of the alexandrite laser treatment time ( $102.8 \pm 20.4$  vs.  $22.3 \pm 5.85$  second,  $n = 38$ ,  $P < 0.01$ ).

Pain assessment 1 hour after the procedure revealed only very mild discomfort in some patients, particularly after the first treatment session (average pain score: 808 nm diode laser:  $0.98 \pm 1.42$  vs. 755 nm alexandrite



**Fig. 1.** Histological changes using a 808 nm linear scanned diode laser. Red arrows do mark a heat based destruction of hair bulbs indicating deep penetration.

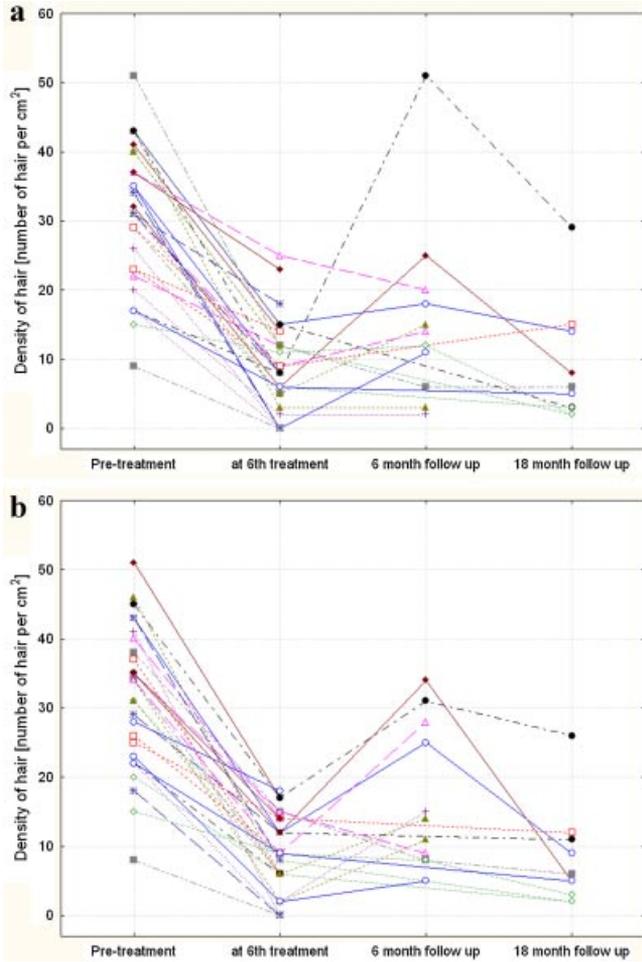


Fig. 2. a and b: Efficacy of laser hair removal immediately after the 6th treatment and at the 6- and 18-month follow-ups, comparing the scanning 755 nm alexandrite laser (a: right axilla) and the linear-scanning long-pulsed diode laser 808 nm (b: left axilla)

laser:  $0.99 \pm 1.76$ ). Three days post-treatment, pain was reported in only exceptional cases in the form of a mild burn (808 nm diode laser:  $0.17 \pm 0.99$  vs. 755 nm alexandrite laser:  $0.16 \pm 0.87$ ;  $P > 0.05$ ).

However, when asked for a direct comparison of diode versus alexandrite laser treatment, 14.9% of patients reported comparable pain with both lasers, only 22.5% reported greater pain with the alexandrite laser, and 62.5% of patients reported greater pain in response to treatment with the diode laser. Nevertheless, despite the increased perception of pain associated with the diode laser, all patients (100%) reported that the discomfort due to pain during treatment with either laser was tolerable.

The pain level did not correlate with the hair density at baseline, the final hair density, or the response to the laser treatment. Moreover, the level of pain was not associated with skin type (Spearman's rank correlation:  $R = 0.04$  [diode laser] and  $R = 0.31$  [alexandrite laser],  $P > 0.05$  for both). Hence, both systems are suitable for skin types I–IV. While pain was also not correlated with hair color at the left axilla using the linear-scanning diode laser at 808 nm ( $R = 0.18$   $P > 0.05$ ), at the contralateral axilla treated with the 755 nm alexandrite laser, pain increased significantly with darker pigmentation of the hair ( $R = 0.58$ ,  $P < 0.05$ ). Possibly, this effect became evident due to the lower pain level (smaller spot size) of the 755 nm alexandrite system.

#### Safety, Adverse Events, and Side Effects

During the study period, no severe adverse events were reported. Treatment-related side effects other than pain were perifollicular edema, erythema, and crusting. Perifollicular edema appeared in response to both systems immediately post-treatment, at diameters up to 2 mm at the left axilla (808 nm diode laser, frequency 13.16%) and up to 4 mm at the right axilla (755 nm alexandrite laser, frequency 38.82%). In concordance with its higher frequency after alexandrite laser epilation, patients rated perifollicular edema more prominent (0 no edema, 10 nettle contact) at the right axilla (755 nm:  $0.57 \pm 0.83$ ) compared to the left axilla (808 nm:  $0.19 \pm 0.52$ ,  $P < 0.05$ ).

Erythema, as a typical sign of heat application to the superficial skin, was present to a minimal extent only (0 no erythema, 10 intense red coloration) in both systems but, again, was slightly more prominent after the alexandrite treatment (755 nm, right axilla  $1.45 \pm 0.78$ ) compared to the treatment of the left axilla (808 nm,  $1.14 \pm 0.70$ ). One hour post-treatment, erythema showed a significantly ( $P < 0.05$ ) lower presence at the left axilla (808 nm,

**TABLE 3. Treatment-Related Side Effects**

Side effects	808 nm	755 nm	<i>P</i> value
Intensity of perifollicular edema (1–10)	$0.19 \pm 0.52$	$0.57 \pm 0.83$	$P > 0.05$
Frequency of perifollicular edema (%)	13.16	38.82	$P > 0.05$
Erythema post-intervention (1–10)	$1.14 \pm 0.70$	$1.45 \pm 0.78$	$P < 0.001$
Erythema 1 hour post-intervention (1–10) (physician's rating)	$1.04 \pm 1.55$	$1.33 \pm 1.90$	$P < 0.05$
Erythema 3 days post-intervention (1–10) (physician's rating)	$0.18 \pm 0.98$	$0.41 \pm 1.42$	$P < 0.05$
Erythema 1 hour post-intervention (1–10) (patient's rating)	$1.33 \pm 1.89$	$1.04 \pm 1.56$	$P < 0.05$
Erythema 3 days post-intervention (1–10) (patient's rating)	$0.17 \pm 0.98$	$0.41 \pm 1.42$	$P < 0.05$
Crusting	None	Single event	n/a
Scarring	None	None	n/a

1.04 ± 1.55) compared to the right axilla (755 nm, 1.33 ± 1.90). Three days post-treatment, few patients reported the persistence of mild erythema: average rating 0.18 ± 0.98 (left axilla, 808 nm) versus 0.41 ± 1.42 (right axilla, 755 nm), with a higher average score on the right side ( $P < 0.05$ ).

## DISCUSSION

Since its introduction in 1995, laser hair removal has proven to be a superior and more permanent solution for unwanted hair compared to other techniques [4,14,15], becoming the third most common elective cosmetic procedure in the United States<sup>1</sup>. Although a number of lasers and non-laser light sources have been developed for purposes of hair removal, the 755 nm alexandrite and 800–810 nm diode lasers remain common options for hair removal among individuals with Fitzpatrick skin types I–IV [16]. Possibly due to an insufficient follow-up period and/or too few treatment sessions, prior studies comparing the efficacy of the alexandrite and diode lasers have yielded mixed results [5,7,11].

The current prospective, single-center, self-controlled study evaluated the long-term efficacy and safety of a newly developed linear-scanning diode laser (808 nm) system (Leda Epi) in comparison to a standard alexandrite 755 nm scanning hair removal laser (EpiCon Study).

Histopathological investigation of laser effects on terminal hair-bearing human skin explants showed comparable levels of thermal damage to the follicle while saving the epidermal compartment. These investigations highlight the safety of both systems tested.

At the 18-month follow-up of 10 study patients, the new linear-scanning diode laser-based hair removal system enabled the operator to achieve an overall hair clearance of 73.71%, compared to 71.90% with the traditional scanning alexandrite system. This result is in line with reported long-term clearing rates for LPDLs and alexandrite lasers (84–85%) [16].

Nevertheless, reports both of alexandrite and of diode laser superiority have been published [7]. This apparent discrepancy may be the result of insufficient follow-up periods and/or too few treatment sessions. First, while a proper assessment of the efficacy of any laser hair removal technique requires that test sites be followed up for a minimum of 6–9 months [9], few prior studies have included a sufficiently long follow-up [16]. The results of the current prospective comparative study, which included the longest follow-up period (18 months) and the highest number of sessions (six treatments) reported to date, clearly show comparable hair reduction with the alexandrite and diode lasers. The study showed continued clinical improvement with each successive treatment session, supported by photo documentation and by exact hair counting using TrichoScan analysis.

These data suggest that 6 treatments with either the alexandrite or the new linear-scanning diode laser every 4 weeks result in stepwise but comparable hair reduction. It remains uncertain whether further treatments would have resulted in increased clearing. Although current guidelines suggest up to eight treatments for optimal results [10] most prior studies comparing the efficacy of alexandrite versus diode lasers tested the effects of only three to four treatments [16].

The 18 months of post-treatment follow-up allowed us to observe that the reduction in hair density continued throughout the follow-up period, despite the cessation of treatment. Interestingly, at the 6-month follow-up, there was a partial recovery of hair growth. This observation is in line with the possibility that terminal hair follicles do not respond uniformly to the heat stress or that incompletely destroyed hair follicles undergo apoptosis over time. Indeed, throughout the treatment period, and up to 18 months of post-treatment follow-up, the hair counts of the alexandrite- and diode-treated axillae were not different. Moreover, patients' self-evaluation with regard to hair clearance did not show a subjective perception of this transient loss in hair clearance.

In addition to laser wavelength, a number of parameters can be manipulated that may influence treatment efficacy. For example, a larger spot size is considered to improve treatment efficacy by enhancing the depth of penetration while also significantly reducing treatment time [10]. Indeed, due to the significantly larger spot size and treatment area per scan made possible by the new technique of linear scanning, the treatment time with the new diode laser in the current study was approximately 21.6% that of the standard alexandrite laser. This might be a great advantage, particularly in larger treatment areas, for example, back and legs. As a possible result of the large spot size of the linear-scanning system, the treatment with this laser was reported to be more painful; meanwhile, the occurrence of certain side effects was more common with the alexandrite laser. Although Bouzari et al. [11] reported similar rates of side effects in response to alexandrite and diode laser hair removal (40 and 46%, respectively), we observed a higher occurrence of erythema and perifollicular edema in axillae treated with the alexandrite laser despite the use of air-cooling devices in both cases. Nevertheless, all side effects observed were transient in nature and resolved within 3 days of treatment. In agreement with our results, Handrick and Alster [7] observed that intra- and post-operative pain was rated mild to moderate with the alexandrite laser but moderate to severe with the diode laser. Because laser hair removal is an elective procedure, pain is an important factor in determining treatment suitability and treatment compliance. Nevertheless, the increased pain of the diode laser may be offset by the significantly reduced treatment time allowed by the relatively larger spot size. In either case, all side effects were resolved within a few days, and all patients rated both treatment options equally tolerable. In agreement with prior investigations [16] we found no evidence of any

<sup>1</sup>Cosmetic Surgery National Data Bank 2010. The American Society for Aesthetic Plastic Surgery. Accessed on June 16, 2011 from: <[http://www.surgery.org/sites/default/files/Stats2010\\_1.pdf](http://www.surgery.org/sites/default/files/Stats2010_1.pdf)>

long-term side effects in response hair removal treatment with either laser.

The current study has a number of limitations that warrant mention. First, due to the relatively low number of patients, comparisons of efficacy and safety of the two lasers according to patient skin type were not possible. To that effect, some preliminary results suggest that the risk of side effects with either the alexandrite or the diode laser is greatest among individuals with skin type IV [7,11]. Additionally, we did not evaluate hair density in a blinded way. Nevertheless, our automatic quantification of axillary hair density using TrichoScan software is an improvement on the manual techniques employed by prior investigations.

In conclusion, the current study illustrates that six treatments with either the alexandrite or the newly developed linear-scanning diode laser every 4 weeks result in significant but comparable hair reduction among individuals with skin types I–IV that persists at least for 18 months after the termination of treatment. Compared to published evidence, the new diode laser system, although significantly faster, produces a hair clearance comparable to that of other diode systems [16]. Additionally, although treatment with the diode laser was reported to be more painful and the occurrence of side effects was more common with the alexandrite laser, all side effects were transient, and all patients rated both treatment options equally tolerable.

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