

Pneumatic Skin Flattening Reduces Pain During Laser Hair Reduction

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Introduction: Laser hair reduction targets melanin pigment within hair shafts, causing heating and an inflammatory response that sends hair into a prolonged telogen phase. Pain may be a limiting factor for patients seeking laser hair reduction.

Methods: We investigate the affect of pneumatic skin flattening (PSF) as compared to conventional treatment using the dynamic cooling device (DCD) on pain during laser hair reduction treatment and evaluated immediately following treatment, as well as the studying its impact on post-treatment effects of laser hair reduction using an alexandrite and Nd:YAG laser to treat the hair in the axillae of 40 volunteer subjects. Thirty-four subjects were treated with a 755 nm, 3 millisecond pulse-duration alexandrite laser using fluences ranging from 16 to 20 J/cm² and an 18 mm circular spot; while six were treated with the 1,064 nm laser with the same parameters but fluences ranging from 22 to 26 J/cm². One axilla of each subject was treated with the PSF device while the other was treated in the conventional manner using the DCD.

Results: PSF reduced the pain of hair removal treatment in 95% of subjects, as compared to conventional laser treatment using the DCD. The mean pain score for the axilla receiving laser treatment using PSF was 2.8 ± 2.1 (mean ± SD) of a possible 10.0. In contrast, the average pain score for the side treated with the DCD was 5.4 ± 2.1 ($P < 0.0001$). Blinded evaluation of post-treatment photographs demonstrated a reduction in erythema on the PSF-treated side immediately post-treatment, and no difference in hair reduction 1 month following treatment.

Conclusions: Pneumatic skin flattening diminishes the pain associated with laser hair reduction. *Lasers Surg. Med.* 40:183–187, 2008. © 2008 Wiley-Liss, Inc.

Key words: laser; hair; pain; pneumatic; skin; flattening

INTRODUCTION

Laser hair reduction utilizes millisecond-domain pulses of red or infrared laser energy to target melanin pigment in hair shafts, causing subsequent heating of the hair shafts, followed by a prolonged resting phase of targeted hair [1–3]. Terminal hair is shed either immediately at the time of treatment or within 1–2 weeks following treatment, with a vellous hair replacing the terminal hair. Because a laser does not distinguish between epidermal melanin and melanin contained in the hair shaft, most hair removal lasers utilize strategies to cool the epidermis, thus protecting it from damage, thereby reducing the pain

and side effects of laser treatment [4–9]. Despite a range of devices used to cool the epidermis, pain often limits a patient's ability to tolerate treatment, or necessitates a reduction in laser energy during treatment, thereby reducing its effectiveness.

An alternative method of pain reduction that may be used with or without cooling is the application of a topical anesthetic to the treatment site prior to treatment [10,11]. A disadvantage of such an approach is the necessity to apply the anesthetic cream at least 20–60 minutes prior to beginning the treatment session. In addition, applying a local, topical anesthetic cream to large skin surface areas may result in excessive systemic absorption of an anesthetic agent such as lidocaine, resulting in systemic toxicity, thus limiting the use of topical anesthetics to smaller treatment areas [12]. Even with the use of topical anesthetics prior to treatment for laser hair reduction, pain reduction is quite variable between patients and between different areas on the same patient.

The present study investigates the ability of a new pneumatic skin flattening (PSF) device to reduce pain during laser hair reduction treatments and compares the PSF device with the dynamic cooling device currently integrated into the laser system. The PSF device utilizes a thin evacuation chamber which generates a negative pressure on the surface of the skin, elevating and flattening the skin against a transparent sapphire window. This device produces a pressure sensation on the skin thereby blocking the sensation of pain. This ability to substitute the sensation of pressure in the brain for pain is referred to as the gate theory of pain control [13–17]. The current study investigates the ability of the PSF device to affect pain during laser hair reduction, and its effect upon post-treatment side-effects and overall efficacy.

MATERIALS AND METHODS

Patients

The protocol was approved by an institutional review board and informed consent was obtained from all subjects.

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Forty subjects ranging in age from 19 to 58, averaging 34 years of age, were included in the study. Subjects had Fitzpatrick Skin Types I–V, with 1 subject having type I skin, 12 having type II skin, 16 having type III skin, 8 having type IV skin, and 3 having type V skin.

Lasers

The lasers used in this study were a 755 nm, 3 millisecond pulse-duration alexandrite laser (Gentle-Lase, Candela Corporation, Wayland, MA), and a 1,064 nm, variable pulse-duration (ranging from 3 to 50 milliseconds) neodymium:yttrium-aluminum-garnet (Nd:YAG) laser (GentleYAG, Candela Corporation).

Laser Treatment

Subjects received laser treatment to one axilla utilizing a dynamic cooling device (DCD) while the contra-lateral side received pneumatic skin flattening (PSF) during laser treatment. Subjects were randomized as to which axillae would receive which treatment. Treatment energies for the alexandrite laser ranged from 16 to 20 J/cm², using an 18 mm-diameter spot and the fixed 3 millisecond pulse-duration, averaging 19.3 J/cm². The treating physician selected either the alexandrite or Nd:YAG laser based upon his assessment of subject skin type and his subjective determination of facultative pigmentation, or degree of tanning, present at the time of treatment. Thirty-four subjects were treated with the alexandrite laser and had skin types ranging from I to V, while six subjects were treated with the Nd:YAG laser and had skin types ranging from II to V. Subjects treated with the Nd:YAG laser were treated using energies ranging from 22 to 26 J/cm² and averaging 24.6 J/cm², using a 3 millisecond pulse-duration and an 18 mm-diameter spot. Identical laser treatment energies were used for both axillae in a given patient.

The lasers used in this study come equipped with a DCD that administers a cryogen spurt prior to firing of the laser pulse. The evaporation of the cryogen cools the surface of the skin thereby selectively protecting the surface of the skin from damage due to superficial absorption of laser

energy [5,7–9]. DCD settings for the alexandrite laser consisted of a 40 millisecond spurt time and a 40 milliseconds delay from the administration of the spurt to the firing of the laser. DCD settings utilized during treatment with the Nd:YAG laser consisted of a 30 millisecond spurt time and a 20 millisecond delay between the cryogen spurt and the firing of the laser.

The PSF vacuum chamber (Candela Corporation) consists of a 26 by 52 mm rectangular vacuum chamber, 7 mm in height, attached to a pump that removes air from the vacuum chamber attaining a negative pressure of 600 millibars within less than 0.2 seconds following the placement of the handpiece on the treatment site (Figs. 1 and 2). Prior to placement of the chamber, a thin layer of ultrasound gel (Parker laboratories, Inc., Fairfield, NJ) is applied to the skin to ensure lubrication and a firm seal. The chamber and gel are both applied at room temperature. The chamber must be of adequate size to ensure activation of a large enough number of pressure receptors in the skin to activate gating in the dorsal horn, and thereby reduce pain. A relatively strong vacuum ensures more efficient compression of pressure receptors. Lask et al. [16] previously demonstrated that the compression level should be above 400 millibars to achieve maximal pain reduction. The vacuum chamber consists of a plastic box covered with an optically coated sapphire window. The window used in the current study was of sufficient size to permit administration of three adjacent laser pulses to be delivered during the 4 second suction time at a rate of approximately 1 Hz.

Data Collection

Pain sensation was evaluated on all treated sites subjectively by subjects after receiving laser treatment. Sites were randomized as to which axilla received treatment using either the PSF device, or conventional treatment using the dynamic cooling device. Pain scores were based on a McGill Pain Questionnaire, which is commonly used in pain evaluation [13–16]. Using this scale, subjects graded pain according to a ten point scale with: 0–1 corresponding to the patient barely feeling the treatment pulses; 2–3 corresponding to the patient feeling

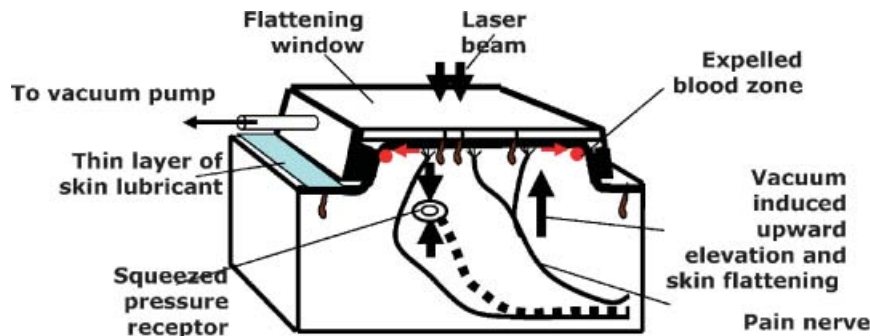


Fig. 1. Schematic representation of the pneumatic skin flattening chamber. A clear plastic window sits atop the pneumatic chamber which is attached to a suction tube. Suction is applied just prior to treatment expelling some blood from the treatment field, stretching skin to reduce melanin concentration per unit area, and bringing the hair follicles closer to the surface. Pain is reduced potentially by all of these mechanisms.

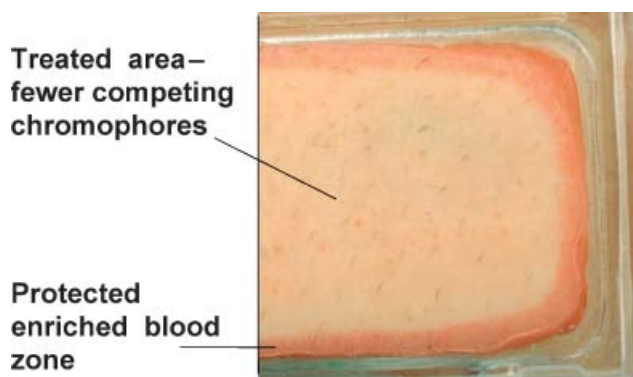


Fig. 2. Skin compressed in the PSF window. Skin compressed in the PSF window demonstrating decreased blood within the compressed area and a zone of increased erythema at the periphery of the device.

the treatment pulses but with little or no pain; 4–5 corresponding to mild and tolerable pain; 6–7 corresponding to acute but still tolerable pain; and 8–10 corresponding to intolerable pain. Subjects also selected the treatment condition they preferred.

The treating physician subjectively evaluated erythema, overall edema, and peri-follicular edema immediately and 20 minutes following treatment, using a 0–3 scale where: 0, no edema or erythema; 1, mild edema or erythema; 2, moderate edema or erythema; and 3, severe erythema or edema.

Cross-polarized, digital photographs were taken of each treatment site prior to treatment, immediately following treatment, and 1 month following treatment, by a professional photographer otherwise uninvolved in the treatment protocols using a 10 megapixel SLR camera with a 105 mm macro lens, and a cross-polarizer to better visualize erythema immediately post-treatment and hair 1 month following treatment (Canfield Scientific, Fairfield, NJ). Photographs taken immediately following treatment were evaluated for erythema and peri-follicular edema, while those taken 1 month after treatment were evaluated for density of hair, by four physician observers blinded as to the treatment conditions. Blinded physician raters used the following scale to rate erythema immediately following treatment from randomized pairs of digital photos: 0, no erythema; 1, 1–25% mild erythema; 2, 26–50% moderate erythema; 3, 51–75% marked erythema; and 4, 76–100% maximal erythema. Blinded physician evaluators rated paired digital photos 1 month following treatment for the degree of hair reduction using the following scale: 0, no perceived hair reduction; 1, 1–25% mild hair reduction; 2, 26–50% moderate hair reduction; 3, 51–75% marked hair reduction; and 4, 76–100% complete hair reduction.

RESULTS

Pain of Treatment

Thirty-six of the subjects rated the treatment using PSF as less painful, while four rated the DCD treatment as less

painful. Of the seven subjects receiving treatment with the Nd:YAG laser, only one found the side receiving the DCD to be less painful; while only 3 of the 36 subjects treated with the alexandrite laser found the DCD side to be less painful. Thus 33 of 36 subjects treated with the alexandrite laser found the PSF side less painful, and 6 of 7 subjects treated with the Nd:YAG laser chose the PSF side as less painful than the side treated with the DCD. The mean pain score for the axilla receiving laser treatment using PSF was 2.8 ± 2.1 (mean \pm SD) of a possible 10.0, with a range of 0–9. In contrast, the average pain score for the side treated with dynamic cooling using a cryogen spray was 5.4 ± 2.1 , and ranged from 2 to 9 (Fig. 3). Paired *t*-test analysis showed the pain reduction afforded by PSF to be statistically significant at the $P < 0.0001$ level.

Post-Treatment Erythema, Edema and Peri-Follicular Edema Evaluated Subjectively

The treating physician rated edema immediately following treatment as an average of 1.8 ± 0.5 (on a 0–3 point scale) for the axillae treated using the DCD, and 1.2 ± 0.7 for the axillae being treated with the PSF device. Edema immediately post-treatment was rated an average of 1.2 ± 0.4 for treatment using the DCD and 1.0 ± 0.3 for the side using the PSF device. Peri-follicular edema was rated as averaging 1.1 ± 0.2 for the side using the DCD, and 1.0 ± 0.0 for the side using the PSF device (Fig. 4a).

Twenty minutes following treatment the same evaluations were made. The ratings for erythema 20 minutes post-treatment averaged 1.3 ± 0.7 and 0.4 ± 0.4 , for the DCD and PSF device treated sides, respectively. For edema 20 minutes post-treatment the ratings averaged 1.0 ± 0.5 and 0.9 ± 0.5 , for the side using DCD and the PSF device, respectively. Peri-follicular edema ratings averaged 0.9 ± 0.4 for both the sides receiving the DCD and, PSF device with their treatments (Fig. 4b).

Blinded Evaluation of Photographs

Four physicians evaluated digital photographs in a blinded fashion for erythema immediately post-treatment and efficacy 1 month following treatment. Erythema of the

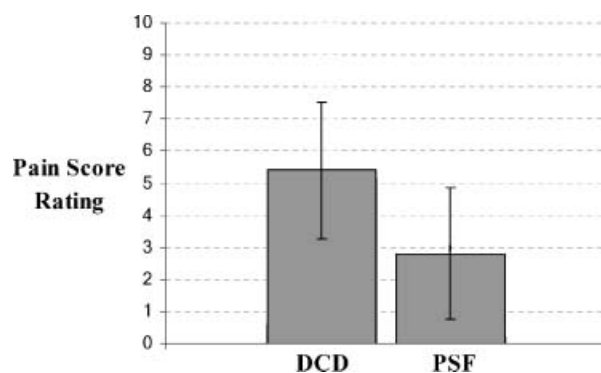


Fig. 3. Pain score ratings. The average pain rating in subjects treated with the PSF device was 2.8 ± 2.1 (mean \pm SD) of a possible 10.0, while the score for the DCD was 5.4 ± 2.1 ($P < 0.001$).

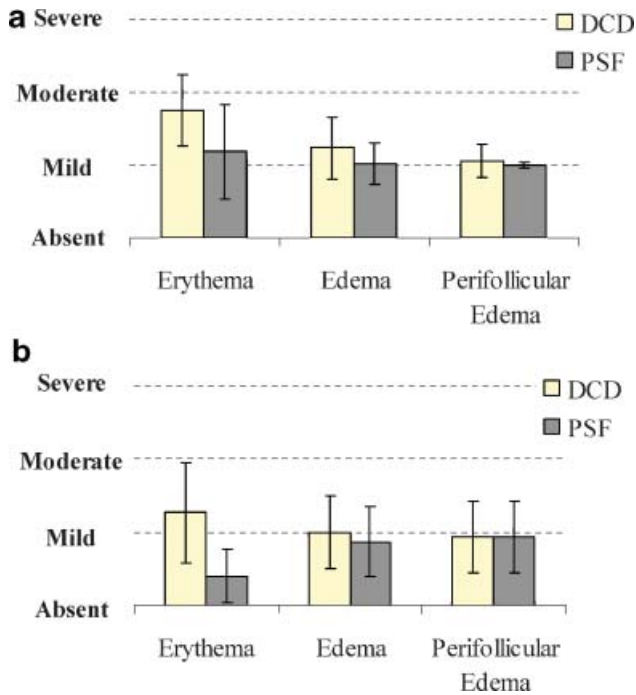


Fig. 4. Erythema, edema and perifollicular edema. Erythema, edema and perifollicular edema ratings are presented on a four-point scale as rated by the treating physician immediately following treatment (a), and 20 minutes following treatment (b).

axillae treated with the PSF device was rated as 0.7 on a four-point scale as compared to 0.9 for the axillae treated with the DCD, and this difference was statistically significant at the $P < 0.05$ level (Fig. 5). There was no significant difference in hair reduction on the side treated using the PSF device as compared to the DCD, with hair reduction measured 1 month following treatment measured at 17% and 18%, respectively, for the side treated with PSF versus the DCD ($P = 0.8$).

DISCUSSION

The PSF device when used in conjunction with laser hair reduction reduced the pain of treatment in a highly



Fig. 5. Digital cross-polarized photograph of erythema immediately post-treatment. A subject photographed immediately post-treatment shows increased erythema on the site treated using the DCD (left panel), as opposed to the site treated using the PSF device (right panel).

statistically significant manner. Thirty-six of 40 subjects rated the treatment administered with the PSF device as less painful than the conventional treatment using the DCD. Thirteen subjects rated the pain a 0 or 1 on a 10-point scale on the PSF-treated side, while no subjects rated pain this low on the DCD-treated side. Skin compression produces a number of effects on treated skin. The primary effect of pain reduction results because compression induces pressure on tactile and pressure neural receptors in the skin, resulting in an afferent inhibition of pain transmission in the dorsal horn. Pain reduction by producing a sensation of pressure is known as the gate control theory of pain reduction. According to the gate theory, nerve impulses from nociceptors (pain inputs) and their sensory fibers (slower and thinner *A-delta* or *C* fibers) arrive at synapses in the spinal cord on their way to the brain. Larger diameter and faster myelinated sensory neurons (*A-alpha* and *A-beta* fibers) carrying pressure and tactile information from the surrounding skin site activate secondary neurons which secrete endogenous opioids into the pain synapse, thus suppressing the flow of pain information to the brain. The gate control theory of pain was first suggested by Wall and Melzack 45 years ago [13–15]. Simply stated, the gate theory describes the difficulty the brain has sensing pressure and pain at the same time; thus, when one is sensing pressure, the sensation of pain has a more difficult time registering in the brain. Skin compression also expels blood from the treatment site, reducing the presence of hemoglobin, a competing chromophore to melanin, during laser hair removal. The reduction of hemoglobin from the light pathway reduces skin heating due to non-target absorption of light, which may reduce pain and side-effects, such as swelling, redness and hyperpigmentation, and also possibly improves efficacy. In addition to decreasing hemoglobin in the treatment field, the skin is stretched, reducing the density of melanin-containing cells per unit area. This may reduce epidermal melanin absorption, possibly lessening side-effects and increasing efficacy of treatment. Finally, by pulling the skin up against a sapphire window, the distance between the treatment beam and the lower portion of the hair follicle may be decreased, thus increasing the amount of light reaching this region, possibly improving the efficacy of treatment.

In our current study, the reduction in pain was significant, as was the reduction in post-treatment erythema immediately following treatment. Some subjects demonstrated a very significant difference in erythema between axillae, with the PSF side evidencing dramatically reduced erythema. This reduction in erythema most likely results from the decreased hemoglobin absorption of laser light due to significant expulsion of blood from the skin as a result of increased pressure on the skin; and possibly to a lesser extent from the reduction of melanin concentration per unit area of skin due to stretching of skin within the PSF window. This author has seen dramatic reductions in hair growth 3 months following treatment with the PSF device versus the DCD in a previous study [17] in isolated subjects (Fig. 6); however this effect was not consistent. In the current study



Fig. 6. Digital cross-polarized photograph of a subject 3 months following treatment in a previous study. More regrowth is present on the side treated using the DCD (**left panel**) as compared to the side treated with the PSF device (**right panel**).

we photographed the axillae 1 month post-treatment to determine if there was a difference in hair growth. None was seen in the current study although isolated subjects demonstrated a significant reduction in hair growth on the side treated using PSF as compared to the DCD, so the only conclusion that can be drawn from this study is that the PSF device and the DCD appear to have no differential effect on hair growth 1 month following a single laser treatment. In future studies it would be beneficial to measure efficacy at a longer time interval from treatment, such as 2–3 months following treatment, and after a series of treatments, to emulate the conditions experienced by most patients undergoing laser hair reduction treatments. Treatment in this study was effective at reducing hair growth when using both the PSF device and the DCD. Treatment time for axillae was short, averaging well under 1 minute. Using the PSF device roughly doubled the treatment times in the current study. New PSF devices which are synchronized with the laser pulse have been developed to shorten treatment times. However, with patients who experience a significant amount of pain during treatment necessitating frequent breaks during a treatment session, using the PSF device should shorten treatment times.

Lask et al. [16] reported substantial pain reduction when using the PSF device and achieving 500 mm HG of negative pressure, and using the device with an IPL, 810 nm diode laser, and a 755 nm alexandrite laser for hair reduction. These authors also demonstrated decreased erythema post-treatment when using PSF, and reported that PSF resulted in equivalent or greater hair reduction than was noted without PSF use when evaluated post-treatment [16]. The likelihood that activating pressure receptors reduces the sensation of pain is supported by the fact that devices that produce pressure on the skin by vibration, but without suction, also reduce the sensation of pain felt during a procedure [15]. The relative contributions to pain reduction of pressure on the skin versus reduction of hemoglobin due to compression of cutaneous blood vessels, can be studied in the future by comparing wavelengths that are strongly absorbed by hemoglobin to those that are not, when using

PSF in association with laser treatments. Our current study demonstrates that PSF used in conjunction with the long pulse-duration alexandrite and Nd:YAG lasers reduces the pain associated with laser treatment in 90% of subjects. A reduction in post-treatment erythema was also seen in the current study, with no effect on treatment efficacy. The PSF device is currently being investigated for its ability to reduce pain associated with other laser treatments including the treatment of pigmented lesions, vascular lesions, and tattoos.

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