A Practical Review of Laser-Assisted Hair Removal Using the Q-Switched Nd:YAG, Long-Pulsed Ruby, and Long-Pulsed Alexandrite Lasers

CHRISTOPHER A. NANNI, MD
TINA S. ALSTER, MD

BACKGROUND. The recent development of numerous laser-assisted hair removal techniques has produced confusion in the field of cutaneous laser surgery.

OBJECTIVES. A systematic review of the hair removal laser systems currently available is attempted. Appropriate patient selection, treatment protocols, and discussion of each system's advantages, disadvantages, and complications is provided.

CONCLUSIONS. Techniques involving the use of selective Q-switched Nd:YAG and long-pulsed alexandrite and ruby laser systems provide a significant delay in hair growth. With further technological advances and understanding of proper treatment parameters and intervals, it is expected that permanent hair removal may eventually be possible. © 1998 by the American Society for Dermatologic Surgery, Inc. Dermatol Surg 1998;24:1399–1405.

The technology of laser-assisted hair removal is advancing rapidly, making it difficult for even the most experienced laser surgeon to keep up with recent developments.

The number of lasers currently available for hair removal and their various treatment protocols have created confusion and hype within the field of cutaneous laser surgery. Magazine and television reports have also served to exaggerate and distort the capabilities of these laser systems, creating unrealistic public expectations. Laser-assisted hair removal is in its infancy with more unanswered questions surrounding this technology than proven facts. Through ongoing clinical trials the optimum treatment wavelengths, intervals, and candidates will be determined. However, at the present time, physicians and scientists need to be clear on the capabilities and limitations of this exciting and promising new laser technology.

The physics of laser-assisted hair removal is best explained in terms of the theory of selective photothermolysis. This theory, proposed by Anderson and Parrish in 1983, states that a wavelength of light used for treatment should correspond to the wavelength preferentially absorbed by a specified target, and must remain in contact with the target no longer than the duration of its thermal relaxation time (the time it takes a target to cool to 50% of its maximum absorbed thermal energy after laser irradiation). For hair removal, the target may be either endogenous such as the pigment within the hair shaft and follicular epithelium or an exogenous substance such as a carbon solution placed within the follicle. The wavelengths of light best used to target follicular pigment are in the red and infrared range of the electromagnetic spectrum. These wavelengths are selectively absorbed by the target chromophore within the follicle which, in turn, generates heat and acoustic waves that disrupt the integrity of the hair follicle preventing hair growth. While this theoretical explanation of laser hair removal seems logical, it is far from complete. Many controversies and unanswered questions in the field of hair biology also cloud the understanding of laser-assisted hair removal. For example, it is unclear which portion of the follicle must sustain an injury in order to prevent hair growth. Both the papilla (at the base of the follicle) and the hair bulge which contains the follicular stem cells (located closer to the epidermis) are logical targets for laser energy and damage.

However, when physician-scientists state that the “hair follicle” is the target for laser energy, they rarely specify exactly which areas they are aiming to destroy. Another unanswered question is whether gray, blonde, or white hairs may be adequately targeted with laser irradiation as these hair colors contain minimal amounts of melanin pigment. Moreover, absorptive differences for phaeomelanin and eumelanin may also limit the ability to treat redheads. Lastly, if an exogenous pigment or dye is used to enhance laser damage to the hair follicle, how does one best introduce the substance into the follicle and is this exogenous pigment necessarily improving the hair removal process?

While the ideal goal of laser-assisted epilation is permanent hair removal, many of the laser systems currently under study have been unable to achieve complete elimination of hair after a single treatment.

Goldberg et al. reported that Q-switched Nd:YAG laser irradiation with pretreatment carbon solution applica-

From the Washington Institute of Dermatologic Laser Surgery, Washington, D.C.
Address correspondence and reprint requests to: Tina S. Alster, M.D., 2311 M Street, N.W. Suite 200, Washington, D.C. 20037.

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tion provides a reduction in hair growth for up to six months.² Nanni and Alster also examined Q-switched Nd:YAG laser irradiation and reported a delay in hair regrowth for up to 6 months regardless of whether or not the area was pretreated with a carbon-containing solution or wax-epilated.³ Grossman et al. investigated a long-pulsed ruby laser system and demonstrated a delay in hair growth for a six month period.⁴ This apparent lack of permanence in laser hair removal has been disappointing but not entirely unexpected. Electrolysis, for example, requires numerous treatment sessions in order to effect a permanent reduction in hair growth.⁵ In a similar manner, it is quite possible that permanent laser epilation will emerge as a reality after multiple treatments.

Q-Switched Neodymium:Yttrium-Aluminum-Garnet (Nd:YAG) Laser-Assisted Hair Removal

The SoftLight laser (Thermolase Corporation, La Jolla, CA) was the first medical laser to be approved for hair removal by the Food and Drug Administration (FDA). The SoftLight laser is a Q-switched Nd:YAG system that produces monochromatic 1064 nm light. Fluences of 2-4 J/cm² are delivered through a 7 mm spot size with a pulse duration of 50 ns and a repetition rate of 10 Hz (Table 1). Hair removal with the SoftLight laser requires pretreatment of unwanted hair-bearing areas with a topical carbon solution (Figure 1), with or without pretreatment wax epilation. The patented technology requires that laser energy be applied to the treatment area only after the pretreatment protocol has been performed.

The SoftLight system uses a carbon-containing topical solution that functions as an exogenous target chromophore for Nd:YAG laser energy. There are two methods by which this exogenous target can be placed into the hair follicle. In the original technique, the hair shaft is first removed by wax epilation thus making room for the carbon-containing solution to be massaged into the empty follicle. The carbon enhanced follicles are then selectively targeted by Nd:YAG laser energy. Through thermally-mediated and photoacoustic effects, the follicle sustains an injury. The injured follicle is then unable to produce or inadequately produces new hair causing, at a minimum, a delay in the hair growth process.⁶ Using the carbon solution apparently provides follicular selectivity independent of the presence of endogenous melanin and, thus, may be helpful when treating individuals with lighter hair colors.

The newest SoftLight technique is performed without pretreatment wax epilation. The carbon particles within the solution have been made smaller in size and can more easily track into the hair follicles using the hair shafts as wicks. However, it remains unclear as to whether a significant amount of carbon penetrates into the follicle to effect hair removal.

The SoftLight technique for hair removal is a patented procedure and can be used only by those practitioners licensed by Thermolase Corporation. The company has opened several centers for hair removal in the U.S. (Spa Thira) where non-practitioners perform the laser treatment. Individual physicians have also contracted with Thermolase under a profit-sharing arrangement to provide the treatment in their offices.

![Figure 1. QS Nd:YAG laser and carbon solution-assisted hair removal (SoftLight) of the upper back. Left: Carbon solution application. Right: Laser "footprint" produced by vaporization of carbon solution upon Nd:YAG laser irradiation.](image-url)
Nd:YAG laser system (Table 1) may be summarized as follows: 1) hair-bearing areas are wax epilated or shaved, 2) a carbon solution is then massaged into the skin, presumably making its way into the hair follicle, 3) the solution is left in contact with the skin for 5–15 minutes, 4) excess surface carbon is gently wiped away, 5) laser energy is then applied to the area until all the black carbon residue is vaporized from the cutaneous surface.

Advantages

The rapid 10 Hz repetition rate of the SoftLight system allows the operator to cover large areas in a matter of minutes. The laser system, if used with pretreatment wax epilation, gives the patient immediate satisfaction with a smooth, hairless surface. The clearest advantage with this laser is its ability to be used on dark skin types with minimal risk of side effects or complications. Virtually any skin type may be treated with mild to moderate discomfort and only a slight risk of dyspigmentation, blistering, or scarring. Overlapping of laser pulses is rarely a concern and may even be beneficial. Intraoperatorically, it is easy to determine the treatment path, as the carbon solution is vaporized from the cutaneous surface with application of laser energy. Therefore, it is not necessary to mark areas with a grid in order to guide the laser treatment path. Lastly, lighter hair colors may conceivably be treated with this system if indeed the carbon particles effectively penetrate the follicles.

Disadvantages

The main disadvantages of the SoftLight process are its patented status which limits the number of physicians that can utilize and study the laser technology, and its lack of long-term hair removal efficacy. The process of using a carbon solution can be messy and time-consuming and is an additional treatment expense. When wax epilation is used as a pretreatment option, pain, folliculitis, and abrasions may occur.

Complications

The SoftLight system appears to be the safest laser-assisted hair removal device. Hypopigmentation or hyperpigmentation may rarely occur. Pain during treatment, especially at the nape of the neck, upper lip, lower back, and areas of redundant or fatty tissue may be problematic. Decreasing energy fluences, stretching the skin tightly, and slowly lasing across a treatment area are helpful in decreasing patient discomfort. Overall, complications and side effects from this laser are less than 1%.27,9

Efficacy

A single Nd:YAG laser treatment results in a delay of hair regrowth for up to three months.2,16 Permanent hair removal may not be achieved even after multiple treatments, as all treated sites tend to experience full hair regrowth by six months, with some patients demonstrating regrowth as early as one and three months.

Many patients claim that the quality of their hair changed after laser treatment and that the regrown hairs were finer in texture and slightly lighter in color. These changes in hair quality are not easily judged by photographic analysis and, therefore, have not been supported by objective data.

Compared to the long-pulsed ruby and alexandrite laser systems, SoftLight removes less hair per treatment session. Although all laser systems delay hair growth for up to six months, the SoftLight process provides less dramatic hair removal during a three to six month period than do the ruby or alexandrite systems discussed below. Whether the delay in hair growth may eventually achieve permanence with repetitive laser treatments or simply represents a prolonged telogen (resting) phase of the hair cycle is unclear. Histologic examination of laser-treated sites will be necessary to fully understand the mechanism of SoftLight laser-assisted hair removal.

Long-Pulsed Ruby Laser-Assisted Hair Removal

The EpiLaser (Palomar Medical Technologies, Beverly MA) was the first long-pulsed ruby laser system approved for hair removal by the FDA. This laser utilizes 694 nm wavelength light and targets endogenous melanin contained in the hair follicle and shaft. A 7 or 10 mm spotsize and a pulse duration of 3 milliseconds is used in order to generate fluences from 10–40 J/cm² with a repetition rate of 0.5 Hz (Table 1). The 694 nm ruby light is absorbed by melanin in the hair shaft and follicle which results in selective thermal damage to the follicle.64 In order to protect melanin-containing structures in the epidermis, a “cooling handpiece” (Figure 2) is concomitantly applied to the skin which decreases its surface temperature and prevents unwanted epidermal thermal injury.64 Intermittent placement of the sapphire tip on the skin thus adequately cools the epidermis, but not the deeper dermis where the hair papilla resides, allowing deeper follicular structures to be thermally damaged.

In addition to providing surface cooling, the EpiLaser sapphire handpiece provides other theoretical advantages. As the operator administers laser pulses, it is recommended that a moderate degree of pressure be applied to the skin surface. This external pressure de-
Figu2. Long-pulsed ruby laser-assisted hair removal (EpiLaser) of calf utilizing the sapphire cooling tip for epidermal protection.

time, number of pulses used, and treatment fluences for each patient. The 694 nm ruby light is also ideal for the treatment of pigmented lesions with hypertrichosis (e.g., Becker’s nevus).  

Disadvantages

The laser is large and generates a moderate amount of heat, requiring its use in a large room with adequate ventilation. The articulated arm may lead to tangling of the peripheral tubing. Debris can collect on the sapphire lens if it is not cleaned regularly and can cause an epidermal burn. A dirty lens is particularly problematic when a treatment area is not shaved closely, allowing singed hair shafts to attach to the lens.

Intraoperatively, it is often difficult to recognize which areas have been lased even when an inked treatment grid is used. The red ink requires removal with alcohol swabs. Treatment may be uncomfortable and even painful when using high fluences or treating sensitive body areas such as the bikini line or upper lip. Blistering, crusting, and pigmentary alteration may occur in dark skin types or tanned skin even with the use of the cooling tip. Hair shafts that are damaged during laser treatment are extruded in 5–7 days, suggesting hair regrowth to the patient. This extrusion phenomenon is particularly common in areas where the hair is coarse such as in the inguinal or axillary creases. These non-viable hairs are easily plucked from the follicle or can be shaved or waxed.

Complications

Perifollicular edema and post-treatment erythema is seen in all patients and resolves rapidly, usually within 1–4 hours. Mild and transient treatment pain occurs in up to 5–10% of patients. Topical or local anesthesia is rarely necessary.

Blistering and/or fine epidermal crusting is experienced in 10–15% of patients and is significantly more common in darker skin phototypes (III and higher) or on tanned skin. Purpura may also occur in darker skin types or in areas of excessive laser pulse overlap. Hypopigmentation may be seen in patients who have had recent sun exposure, but long-term complications and scarring are rare.

Long-Pulsed Alexandrite Laser-Assisted Hair Removal

Several long-pulsed alexandrite (755nm) laser systems are currently available, including the LPIR (Long-Pulsed-Infra-Red) laser (Cynosure, Chelmsford, MA), the EpiTouch (Sharplan/ESC, Needham, MA) and Gentle Lase (Candela, Wayland, MA). These systems typically use a 7 or 10 mm spotsize, or in the case of
with darker skin tones or tanned skin may be helpful but will not guarantee that subsequent treatment sessions will be free of complications. Post-treatment erythema and burning can be alleviated with cold compresses or mild topical corticosteroid application.

Advantages

The long-pulsed alexandrite systems are compact which enable them to be operated in a small room with adequate ventilation. The flexible fiberoptic arm of each unit is easy to manipulate and enables easier access to hard-to-reach body areas. The large spot or scan size and rapid (1–5 Hz) repetition rate make the treatment of large areas such as the back or legs more manageable. The 755 nm wavelength is theoretically less likely to be absorbed by epidermal melanin than other pigment-specific lasers (eg, 694 nm ruby) and may, thus, be less damaging to darker skin types. The laser handpiece is simple to use and allows the operator a clear view of the treatment site because of its small size. The laser is equipped with a red helium-neon aiming beam which is also helpful in directing handpiece position.

Disadvantages

The use of a cooling gel is messy and time-consuming, slowing overall treatment time. In large anatomic locations, it is often difficult to recognize which areas have been lasered even when a treatment grid is used. The inked treatment grid often requires alcohol swabs for removal. Treatment may be uncomfortable and even painful when using high fluences, faster repetition rates, or treating sensitive body areas such as the bikini line or upper lip. Blistering, crusting, and pigmented alteration may occur in dark skin types or tanned skin even when a cooling gel or device is utilized. Extrusion of damaged hair shafts (particularly coarse ones) occurs within a week after the procedure and may be mistaken for hair regrowth by the patient, but can easily be removed with tweezing.

Complications

Perifollicular edema and post-treatment erythema is seen in all patients and resolves rapidly, usually within 1–4 hours. Mild and transient treatment pain occurs in up to 10% of patients. Moderate pain requiring topical or local anesthesia is rarely necessary. Blistering and/or fine epidermal crusting is experienced in 10–15% of patients and is significantly more common in darker skin types (III and higher) or on tanned skin. Purpura may also occur in darker skin types or in areas of excessive laser pulse overlap but long-term complications and scarring are rarely seen.
After three laser treatments at 4–6 week intervals, patients experience a marked delay in hair regrowth (6–9 months) and many patients report a "permanent" reduction in hair density.4–6,8,9

Laser-Assisted Hair Removal Treatment Pearls
- Do not treat tanned skin
- Do not overlap laser pulses
- Use a red-inked treatment grid (for ruby and alexandrite systems)
- Test sites helpful but not infallible
- Shave hair (don't pluck or wax) prior to lasing
- Use micronized carbon solution (for SoftLight system)
- Cooling gel necessary (for systems without cooling tip or device)
- Wipe lens every 5–10 pulses (for contact cooling tips)
- Increase energy fluences as tolerated
- Use topical steroids to decrease post-treatment erythema
- Do not treat prior to important social or professional events.

Basic Laser Set-Up
- Disposable razor
- Red marking pen or ink grid
- Cooling gel
- Carbon solution +/- wax
- 4 x 4 gauze
- Alcohol swabs
- Mild topical steroid cream
- Safety goggles.

Additional Long-Pulsed Lasers and Light Sources Available For Hair Removal

Long-pulsed ruby laser systems available for hair removal without the cooling sapphire tip handpiece include the Chromos 694 (Mehl Biophile, Gainesville, FL) and EpiTouch (Sharplan Lasers, Allendale, NJ) lasers (Table 1). These lasers utilize a cooling gel to decrease epidermal surface temperature and follow pre- and post-treatment protocols similar to the Palomar Epilaser.

A flashlamp powered light source (Table 1) that utilizes filters to produce bands of light in specific groups of wavelengths is available and marketed under the name of EpiLight (ESC Medical, Needham, MA). An on-board computer generates energy fluences, wavelengths, and pulse durations based upon certain patient characteristics such as skin and hair color. Energy from the EpiLight is transmitted through a surface gel which cools the skin.
Pearls

Laser-assisted hair removal using the Q-switched Nd:YAG and long-pulsed alexandrite and ruby laser systems is a relatively new process. It is too early to predict which treatment protocols, patients, and energy settings will be ideal to achieve either long-lasting or permanent hair removal. At the present time, physicians must be content to provide their patients with a significant delay in hair growth. This achievement in laser technology can profoundly affect the quality of patients’ lives, providing them with a safe, rapid, and relatively painless method for long-lasting hair removal.

References


Commentary

Laser-assisted hair removal is a burgeoning field that has demonstrated significant interest amongst the dermatologic surgery community and the lay public. While relatively embryonic in its development, the field of laser-assisted hair removal has begun to demonstrate significant cosmetic benefit to many patients. The interest in this field is demonstrated by the proliferation of laser systems and techniques developed for the purpose of long-term hair removal. Both physicians and patients alike have been overwhelmed by the claims of laser manufacturers regarding the potential efficacy of the various systems available for hair removal in view of the large potential market.

This paper by Nanni and Alster helps clarify the use of the Q-switched Nd:YAG, long-pulsed alexandrite and long-pulsed ruby laser systems as it relates to hair removal. While this field is relatively new, studies such as this are critical in helping both the physicians and the public sort out the differences among the various therapeutic options that are available. It is clear from this study and my own experience that multiple variables need to be considered in determining whether or not laser assisted hair removal is appropriate for a particular patient, and subsequently which technique to utilize. Such factors will be based upon hair color, the diameter of the hair shaft, skin phenotype of the patient, the stage of the hair follicle growth cycle, hormonal factors, the anatomical location of the hair and treatment intervals. As the medical community learns more of the various critical factors involved in determining the ideal patient for this procedure, modifications of laser technology will continue to evolve providing the physician with an increasing number of therapeutic options.

Nanni and Alster describe the benefits and limitations of three laser systems; however, additional laser systems and light sources are available to the physician at this point in time. These systems include the Diode, Q-switched Nd:YAG without an exogenous chromophore, an intense pulsed light source as well as photodynamic therapy. Despite a recent claim by Dierickx et al. in the July 1998 Archives of Dermatology claiming that permanency can be obtained through the use of the long-pulsed ruby laser, it is generally believed that none of these laser systems or techniques provide more than a clinically significant delay in hair regrowth as stated by Nanni and Alster. As laser technology continues to evolve with our understanding of many factors that influence follicle destruction, it is hoped that comprehensive studies will substantiate the specific value of these techniques.

ROY G. GERONEMUS, MD