Optimizing Treatment Parameters for Hair Removal Using a Topical Carbon-Based Solution and 1064-nm Q-Switched Neodymium:YAG Laser Energy

Christopher A. Nanni, MD; Tina S. Alster, MD

Objective: To determine the most effective treatment parameters for laser-assisted hair removal using a Q-switched neodymium:yttrium-aluminum-garnet (Nd:YAG) laser.

Design: Prospective study to determine the effectiveness of Q-switched Nd:YAG laser-assisted hair removal under varying pretreatment protocols. Hair growth was assessed after laser treatment, and the results were compared with those of wax epilation at 4, 12, and 24 weeks.

Setting: A private ambulatory laser facility and academic referral center.

Intervention: Laser-assisted hair removal was performed under 4 different pretreatment conditions. Eighteen areas of unwanted body and facial hair from 12 study subjects were divided into 4 quadrants. Wax epilation followed by application of a carbon-based solution and exposure to Q-switched Nd:YAG laser radiation was performed on 1 quadrant. A second quadrant was wax epilated and exposed to Q-switched Nd:YAG laser radiation without prior carbon solution application. A third quadrant was exposed to laser radiation alone, and a final quadrant was wax epilated to serve as the control. Follow-up evaluations at 1, 3, and 6 months consisted of photographic documentation, manual hair counts, and patient hair-density estimates.

Main Outcome Measure: Percentage of hair regrowth as assessed by objective hair counts and patient subjective evaluations.

Results: Mean percentage of hair regrowth at 1 month was 39.9% for the wax-carbon-laser quadrant, 46.7% for the wax-laser quadrant, 66.1% for the laser-alone quadrant, and 77.9% for the wax control quadrant. The percentage of hair regrowth approximately doubled by 3 months but was significantly delayed in all laser-treated quadrants regardless of pretreatment protocol. Full hair regrowth in all anatomic locations was observed by month 6. Patient subjective evaluations of hair density closely approximated hair count data. No adverse effects or long-term complications were observed.

Conclusions: A single hair-removal treatment with the Q-switched Nd:YAG laser is safe and effective in delaying hair growth for up to 3 months. Although the combination of pretreatment wax epilation and topical carbon solution application was effective, laser irradiation alone, with or without wax epilation, also provided a significant delay in hair growth.

Arch Dermatol. 1997;133:1546-1549
SUBJECTS AND METHODS

Twelve subjects (3 men and 9 women; mean age, 32 years) were enrolled in the study. A total of 18 anatomic locations were evaluated, including 6 backs, 3 upper lips, 1 chin, and 8 legs. Potential subjects with evidence of endocrine dysfunction, immune suppression, recent oral retinoid use, drug-induced hypertrichosis, sensitivity to infrared light, photosensitivity, collagen vascular disease, or androgen-producing tumor were excluded. Skin type, sex, hair-removal history, and patient age were recorded. All skin types were considered for inclusion, although only skin types 1 through IV were represented. Only subjects with black or brown terminal hair were included.

A Q-switched Nd:YAG laser (Thermolase Corp) was used at a fluence of 2.6 J/cm², a wavelength of 1064 nm, a pulse duration of 50 nanoseconds, a 7-mm spot size, and a pulse repetition rate of 10 Hz. Study areas on the back and legs were divided into 3-cm² quadrants using a standard template. Facial areas were divided into 1-cm² quadrants using a smaller template. Treatment sites were placed in a linear fashion, with orientation and location randomized for each anatomic area. Pretreatment protocol in 1 quadrant consisted of wax epilation and carbon-based solution application (Thermolase Corp) with subsequent laser irradiation using the above set parameters. A second quadrant was wax epilated (without carbon solution) and exposed to laser radiation. A third area was exposed to laser radiation without any pretreatment waxing or carbon solution application. The last quadrant was simply wax epilated and served as a control. Those sites pretreated with carbon solution retained a thin film of surface carbon after gentle wiping of excess solution with dry gauze. The pretreated skin was subsequently irradiated within 15 minutes after the application of carbon solution.

Evaluations at 1, 3, and 6 months after treatment consisted of consecutive photographic documentation using identical lighting, camera, and patient positioning (Mirror Image System, Virtual Eyes Inc, Kirkland, Wash); manual hair counts; and subjective patient hair-density estimates. Hair-density estimates were based on each patient's subjective evaluation using a scale of no hair growth, minimal or moderate growth, and thick hair growth as options.

The number of terminal hairs present after treatment were compared with baseline hair counts. The percentage of hair regrowth was defined as the percentage of hairs that were present after treatment compared with baseline hair counts. Anatomic locations were grouped and analyzed separately. The percentage of hair regrowth was calculated for each study quadrant. Paired-difference t tests were used to compare treatments. Wilcoxon signed-rank tests of the paired differences were also performed for confirmation. Hochberg improved Bonferroni procedure was used to maintain a joint significance level of .05 for the 4 tests within a single time point.

RESULTS

Hair regrowth was evaluated by hair counts and subjective patient evaluations of hair density at each of the 3 follow-up visits (at 1, 3, and 6 months). The mean percentage of regrowth (Figure 1) at 1 month was 39.9% (P<.001) for the wax-carbon-laser quadrants, 46.7% (P<.001) for the wax-laser quadrants, 66.1% (P=.10) for the laser-alone quadrants, and 77.9% for the wax control quadrants (Figure 2 and Figure 3). At the 3-month follow-up, all laser-treated quadrants had significantly less hair regrowth than the control quadrant, with a mean of 79.1% (P=.006) for the wax-carbon-laser quadrants, 85.2% (P=.01) for the wax-laser quadrants, 86.3% (P=.02) for the laser-alone quadrants, and 102.2% for the wax control quadrants (Figure 4 and Figure 5). Each percentage of regrowth was well approximated by a nor-
Waxing + Solution + Laser
Waxing + Laser
Waxing Alone
Laser Only

Figure 3. Same area as in Figure 2 one month after Q-switched neodymium:yttrium-aluminum-garnet (Nd:YAG) laser treatment with various pretreatment preparations using a wax-epilated region as a control. Treatment areas demonstrate 20% regrowth in Waxing + Solution + Laser site, 24% regrowth in Waxing + Laser site, 85% regrowth in Waxing Alone (control) site, and 61% regrowth in Laser Only site.

Waxing + Solution + Laser
Waxing + Laser
Waxing Alone
Laser Only

Figure 4. Region seen in Figures 2 and 3 three months after 1 treatment. Treatment areas demonstrate 35% regrowth in Waxing + Solution + Laser site, 40% regrowth in Waxing + Laser site, 94% regrowth in Waxing Alone (control) site, and 77% regrowth in Laser Only site.

Waxing + Solution + Laser
Waxing + Laser
Waxing Alone
Laser Only

Figure 5. Six-month follow-up photograph shows full hair regrowth in all treatment areas.

Figure 6. Patient hair-density estimates.

Hair removal has become a major research interest and economic force within the field of cutaneous laser medicine. Laser systems with differing wavelengths, pulse durations, and energy densities are currently under development for hair removal, based largely on unproven theories and vague mechanisms of action. While the theory of selective photothermolysis could be used to optimize wavelengths and pulse durations for laser epilation, the exact target within the hair follicle has yet to be clearly established. The hair matrix, papilla, and bulge are all potential areas of hair follicle vulnerability. However, without knowledge of a specific follicular target, it becomes difficult to predict which laser wavelengths and pulse durations will be most successful.

At the time of study initiation, only 1 laser-assisted hair-removal device had been approved for use by the Food and Drug Administration (the SoftLight system by Thermolase Corp). This system uses energy from a Q-switched Nd:YAG laser following pretreatment wax epilation and application of a patented carbon-based topical solution. It provides an exogenous target chromophore (eg, carbon) to which 1064-nm-wavelength laser light has an affinity. The carbon is theoretically placed within wax-epilated follicles, and laser-induced thermal and photoacoustic damage is subsequently produced within the follicular structure. Selective damage, then, remains independent of the presence of endogenous melanin.

The results of this study suggest that after a single Q-switched Nd:YAG laser treatment, a change within the hair follicle is produced that results in a delay of hair regrowth. However, permanent hair removal (cessation of hair growth in treatment areas for the lifetime of the pa-

COMMENT

Hair removal has become a major research interest and economic force within the field of cutaneous laser medicine. Laser systems with differing wavelengths, pulse durations, and energy densities are currently under development for hair removal, based largely on unproven theories and vague mechanisms of action. While the theory of selective photothermolysis could be used to optimize wavelengths and pulse durations for laser epilation, the exact target within the hair follicle has yet to be clearly established. The hair matrix, papilla, and bulge are all potential areas of hair follicle vulnerability. However, without knowledge of a specific follicular target, it becomes difficult to predict which laser wavelengths and pulse durations will be most successful.

At the time of study initiation, only 1 laser-assisted hair-removal device had been approved for use by the Food and Drug Administration (the SoftLight system by Thermolase Corp). This system uses energy from a Q-switched Nd:YAG laser following pretreatment wax epilation and application of a patented carbon-based topical solution. It provides an exogenous target chromophore (eg, carbon) to which 1064-nm-wavelength laser light has an affinity. The carbon is theoretically placed within wax-epilated follicles, and laser-induced thermal and photoacoustic damage is subsequently produced within the follicular structure. Selective damage, then, remains independent of the presence of endogenous melanin.

The results of this study suggest that after a single Q-switched Nd:YAG laser treatment, a change within the hair follicle is produced that results in a delay of hair regrowth. However, permanent hair removal (cessation of hair growth in treatment areas for the lifetime of the pa-

ARCH DERMATOLOGY/VOL 133, DEC 1997
1548

mal distribution. All hypothesis tests and associated P values are 2 sided.

Patient subjective hair-density estimates reflected the objective hair count data (Figure 6). Full hair regrowth occurred in all study quadrants based on hair counts and patient hair-density estimates by the 6-
tient) was not achieved. All treatment sites exhibited full hair regrowth by 6 months, with some patients demonstrating regrowth as early as 1 and 3 months. While the ideal goal of laser-assisted epilation is permanence, the results of this study are consistent with those of previous studies involving single-session laser hair removal. Goldberg\textsuperscript{1} reported that Q-switched Nd:YAG laser treatment and application of carbon solution provided a reduction in hair growth for up to 6 months. Grossman et al\textsuperscript{3} reported a delay in hair growth for a 6-month period after long-pulsed normal-mode ruby laser irradiation. This apparent lack of permanence after laser hair removal has been disappointing, but not entirely unexpected, considering the vulnerability of hair to treatment at different phases in its growth cycle. Electrolysis, for example, requires numerous treatment sessions to effect a permanent reduction in hair growth.\textsuperscript{7} In a similar manner, it is quite possible that permanent epilation will emerge a reality only after multiple laser treatments.\textsuperscript{2,3} Repeated laser injury to the hair follicle, which was not examined in the current study, should be investigated. Future studies should also address the question of whether laser light simply induces a prolonged telogen hair cycle or whether irreversible follicular damage is possible. Ultimately, histologic examination of treated hirsute sites will be necessary to fully understand the mechanisms of laser-assisted hair removal.

Although pretreatment with wax epilation and a topical carbon solution resulted in significant hair removal, this protocol was not essential. All laser-treated sites showed less hair regrowth at 3 months than the wax-epilated control quadrants, suggesting that the laser energy can target the follicle without an exogenous carbon chromophore. However, because of the limited number of anatomic regions treated in this study, we lacked the statistical power to determine if a particular pretreatment protocol was superior to another.

It is interesting to note that the quadrants that were simply exposed to laser radiation without waxing or carbon solution did not show a significant reduction in hair growth until the third month. This finding may be attributed to the fact that, in areas that were not wax epilated, laser irradiation caused the terminal hairs to whiten but to remain in the follicles. Although the hair shafts were injured, hair counts at 1 month included these depigmented hair shafts. By the third month, however, the injured hairs had fallen out of the follicles and a significant reduction in hair counts was recorded.

While the results of this study suggest that wax epilation and/or carbon-based solution application is not essential to the laser-assisted hair-removal process, it is important to note that all study subjects had brown or black hair. When blonde or white hair-bearing areas are being treated, exogenous carbon pigment application may play a more important role in selectively targeting and concentrating laser energy into the follicle. Presumably, melanocytes and melanin within the hair follicle and shaft are the primary targets of Q-switched Nd:YAG laser energy when the laser treatment is used without a carbon solution. These melanin-producing cells are located within the hair matrix at the base of the follicle, the infundibulum, and sparsely within the outer root sheath.\textsuperscript{8,9} As there are greater numbers of melanocytes within the hair follicle than there are within the epidermis, laser energy can pass through the skin surface and be absorbed selectively by follicular melanin.\textsuperscript{9} This selective process obviously becomes more problematic when lighter hair colors are being treated. Gray hair, for instance, has fewer melanocytes at the hair bulb, and blonde hair has a decreased number of partially pigmented melanosomes as compared with black hair.\textsuperscript{8} Therefore, exogenous pigment in the form of a carbon-based solution may be helpful in the treatment of individuals with lighter hair colors.

In conclusion, a single treatment with a Q-switched Nd:YAG laser results in a greater delay of hair growth (up to 6 months) when compared with wax epilation alone. Regardless of the use of pretreatment wax epilation or carbon topical solution, hair growth was decreased when compared with control (waxed) areas. Complete hair regrowth occurred by 6 months after a single treatment, suggesting that further research is needed to determine the optimal treatment intervals, energy settings, wavelengths, and pulse durations needed to achieve longer-lasting or permanent laser-assisted hair removal.

Accepted for publication August 18, 1997.


REFERENCES