

Long-Pulsed Nd:YAG Laser-Assisted Hair Removal in Pigmented Skin

A Clinical and Histological Evaluation

Tina S. Alster, MD; Holly Bryan, BS; Carmen M. Williams, MD

Objective: To determine the safety and effectiveness of a long-pulsed Nd:YAG laser at 1064 nm in effecting long-term hair reduction in patients with darkly pigmented skin.

Design: Nonrandomized before-after clinical and histological trial.

Setting: Private practice, ambulatory care facility.

Patients: Twenty women with skin phototypes IV through VI and dark brown to black terminal hair on the face, axillae, or legs.

Intervention: A series of 3 long-pulsed (50-millisecond) 1064-nm Nd:YAG laser treatments at fluences ranging from 40 to 50 J/cm² were delivered to the identified treatment areas on a monthly basis by a single operator.

Main Outcome Measures: Global clinical grading scores of comparable before-after treatment photographs were determined by 2 independent medical as-

sessors during each laser session and 1, 3, 6, and 12 months postoperatively. A dermatopathologist reviewed unmarked histological specimens obtained at baseline, immediately after the initial laser treatment, and at 1 and 6 months after the final laser session.

Results: Substantial hair reduction was seen after each of the 3 treatment sessions. Prolonged hair loss was observed 12 months after the final laser treatment (70%-90% hair reduction). Axillary hair was substantially more responsive to laser irradiation than was hair located on the legs and face. Adverse effects included mild to moderate treatment pain and rare occurrences of vesiculation and transient pigmentary alteration without fibrosis or scarring. Histological tissue changes mirrored clinical response rates, with evidence of selective follicular injury without epidermal disruption.

Conclusion: The long-pulsed 1064-nm Nd:YAG laser is a safe and effective method of long-term hair reduction in patients with darkly pigmented skin.

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THE CLINICAL results achieved by laser hair-removal systems since 1995 constitute an impressive but essentially qualified success. The difficulty in permanently disrupting hair growth through laser irradiation results from the superlative ability for follicular self-repair and regeneration and from the varying anatomical locations, sizes, depths, and melanin concentrations of hair. Further complicating the process, it is not yet known which portion of the hair follicle is primarily responsible for hair growth and whether the integrity of the entire follicular epithelium is essential to the hair growth process. Because of these uncertainties, current laser hair-removal systems are designed to irradiate as much of the follicle as possible. Thus, only lasers

emitting energy with wavelengths ranging from 630 to 1100 nm are potentially capable of irradiating the entire length of anagen hair follicles, which typically extend 2 to 5 mm into the dermis.

Although several dermatologic lasers meet the wavelength criteria for effecting selective follicular destruction, the treatment of darker skin phototypes is particularly problematic because follicular melanin serves as the intended chromophore for laser epilation. Thus, absorption of laser energy by the targeted hairs is compromised by an increased concentration of epidermal melanin in these patients. To reduce epidermal energy absorption relative to follicular absorption, longer-wavelength lasers are best used. The 1064-nm Nd:YAG laser can penetrate from 5 to 7 mm into the dermis, depths more

From the Washington Institute of Dermatologic Laser Surgery, Washington, DC.

MATERIALS AND METHODS

Twenty women (aged 21-39 years) with unwanted dark brown to black terminal hairs and skin phototypes IV to VI were included in the study after informed consent was obtained. Three consecutive, long-pulsed (50-millisecond) 1064-nm Nd:YAG laser treatments were delivered on a monthly basis to the involved treatment areas by a single operator (T.S.A.). Immediately before each treatment, hairs longer than 1 mm were shaved close to the skin using a safety razor. No topical cooling gel or anesthetic cream was used. A contact sapphire-tipped cooling device was used to protect the skin during laser irradiation with a rhomboid scanner that placed adjacent nonoverlapping 5-mm spots over the treatment area (Lyra; LaserScope, San Jose, Calif). Facial hair was treated with a mean fluence of 40 J/cm² in 8 patients. A mean fluence of 50 J/cm² was used to treat axillary hair in 8 patients, whereas a mean fluence of 45 J/cm² was used on the legs in 4 patients (**Table**). Photographs using identical lighting, patient positioning, and camera equipment were obtained of all treatment sites before each of the 3 treatment sessions and at 1, 3, 6, and 12 months after the final treatment.

Global clinical evaluations of hair loss and extent of hair regrowth using side-by-side comparison photographs were performed by 2 independent medical assessors at each visit with the use of the following hair reduction grading system: 0 indicates less than 25%; 1, 25% to 50%; 2, 51% to 75%; 3, 76% to 90%; and 4, greater than 90%. Subjective patient reports and adverse effects were also recorded at each follow-up visit.

Three-millimeter skin punch biopsy specimens were taken from within each of the 3 different treatment areas (face, axilla, and leg) at baseline, immediately after laser irradiation, and 1 and 6 months after the final laser treatment in 3 patients. Histological evaluations were performed by a board-certified dermatopathologist unaware of the study protocol (C.M.W.).

than sufficient to reach the base of the bulb in most anatomical areas, and would thus be expected to produce sufficient follicular injury with less epidermal damage in patients with pigmented skin. It would also be anticipated that significantly fewer instances of crusting, vesiculation, dyspigmentation, and other adverse epidermal effects would occur with 1064-nm Nd:YAG laser irradiation. The purpose of this study was to determine the efficacy and safety profile of a long-pulsed (50-millisecond) 1064-nm Nd:YAG laser for hair reduction in patients with dark skin tones.

RESULTS

A marked reduction in hair regrowth was noted after each of the 3 treatment sessions and persisted for 12 months after the final treatment in all body locations studied (**Figure 1** and **Figure 2**). Clinical hair reduction scores

on the face averaged 1.8 after 1 treatment, 2.3 after 2 treatments, 2.9 after 3 treatments, and 3.1, 2.5, and 2.3 at 3, 6, and 12 months, respectively, after the third treatment. Hair on the legs was slightly more responsive, with clinical hair reduction scores of 2.0, 3.2, and 3.5 at 1 month after each of the 3 treatments, and 3.3, 3.0, and 2.9 at 3, 6, and 12 months, respectively, after the final laser session. Axillary hair demonstrated the most impressive hair reduction scores, averaging 2.8 after 1 treatment, 3.6 after 2 treatments, and 4.0 at 1 and 3 months, 3.8 at 6 months, and 3.5 at 12 months after the third treatment (**Figure 3**).

Adverse effects (calculated from all 60 treatment sessions) were limited to mild to moderate treatment pain in 90% of treatment sites, transient pigmentary alteration in 5% (exposed facial or leg areas only; average duration, 4 weeks), and vesiculation in 1.5%. Fibrosis and scarring were not seen in any treatment site as a result of laser irradiation.

Histological changes mirrored clinical response rates, with evidence of selective follicular injury without epidermal disruption. Destruction of large terminal hair follicles was evident with minimal inflammation, reduced numbers of hair shafts, and preservation of pilosebaceous glands at 6 months after the series of 3 laser treatments. (**Figure 4**).

COMMENT

Laser hair-removal systems are typically grouped into the following 3 categories on the basis of the type of laser or light source each uses: red-light systems (694-nm ruby), infrared-light systems (755-nm alexandrite, 800-nm diode, and 1064-nm Nd:YAG), and intense pulsed-light sources (590- to 1200-nm). Although technological advances of laser-assisted hair removal during the past 5 years have been highly gratifying, the rapidity of development has not been entirely without drawbacks. Specifically, none of the systems are able to produce consistent, absolutely predictable results, as follicular responses to laser irradiation vary considerably from patient to patient, from one anatomical site to another, and from one treatment time to another for any given individual. Compared with other cutaneous organelles, hair follicles represent a unique challenge for implementation of the theory of selective photothermolysis, based largely on the fact that it remains unclear which portion of the follicle is the preferred target to effect hair destruction. Despite this monumental obstacle, most of the available lasers and intense light sources can achieve a marked delay in the regrowth of unwanted hair (typically 3-9 months), although longer delays have been observed.¹⁻¹¹ In addition, laser-assisted hair removal is associated with low treatment discomfort, and large body areas can be treated expeditiously, since follicles need not be targeted individually (as is the case with electrolysis).^{12,13} Paramount to the success and acceptability of lasers for epilation has been the substantial safety margin afforded by most systems, with transient and mild adverse effects being normal.¹⁴

Ideal candidates for laser-assisted hair removal have traditionally included those individuals with pale skin

Patient Characteristics and Global Clinical Grades

Patient No.	Skin Type	Fluence, J/cm ² *	Status After Treatment, Grade*						
			1 mo After		Third Treatment				
			First Treatment	Second Treatment	1 mo	3 mo	6 mo	12 mo	
Face									
1	V	40	2.0	2.5	3.0	3.5	3.0	3.0	3.0
2	V	40	1.5	2.0	2.5	2.5	2.0	2.0	2.0
3	IV	45	2.5	3.0	3.5	4.0	4.0	4.0	3.0
4	V	40	2.0	2.5	3.0	3.0	2.5	2.5	2.5
5	VI	35	2.0	2.0	2.5	3.0	2.0	2.0	2.0
6	V	40	2.0	2.5	3.0	3.0	2.5	2.0	2.0
7	V	40	1.5	2.0	3.0	3.0	2.0	2.0	2.0
8	V	40	1.0	2.0	2.5	2.5	2.0	2.0	2.0
Mean	...	40	1.8	2.3	2.9	3.1	2.5	2.3	2.3
Axilla									
9	IV	50	2.5	3.0	4.0	4.0	4.0	4.0	3.5
10	IV	45	2.0	3.0	4.0	4.0	3.0	3.0	3.0
11	V	50	3.0	4.0	4.0	4.0	4.0	4.0	4.0
12	V	50	3.0	3.5	4.0	4.0	4.0	4.0	3.0
13	V	50	3.0	4.0	4.0	4.0	4.0	4.0	4.0
14	V	50	3.0	3.5	4.0	4.0	3.5	3.0	3.0
15	VI	55	3.0	4.0	4.0	4.0	4.0	4.0	4.0
16	V	50	3.0	4.0	4.0	4.0	4.0	4.0	3.5
Mean	...	50	2.8	3.6	4.0	4.0	3.8	3.5	3.5
Leg									
17	V	40	2.0	3.0	3.0	3.0	3.0	3.0	3.0
18	V	45	2.0	3.5	4.0	3.5	3.0	3.0	3.0
19	IV	45	2.0	3.0	3.0	3.0	3.0	2.5	2.5
20	IV	50	2.0	3.5	4.0	4.0	3.0	3.0	3.0
Mean	...	45	2.0	3.2	3.5	3.4	3.0	2.9	2.9

*Zero indicates less than 25% reduction; 1, 25% to 50% reduction; 2, 51% to 75% reduction; 3, 76% to 90% reduction; 4, greater than 90% reduction; and ellipses, not applicable.

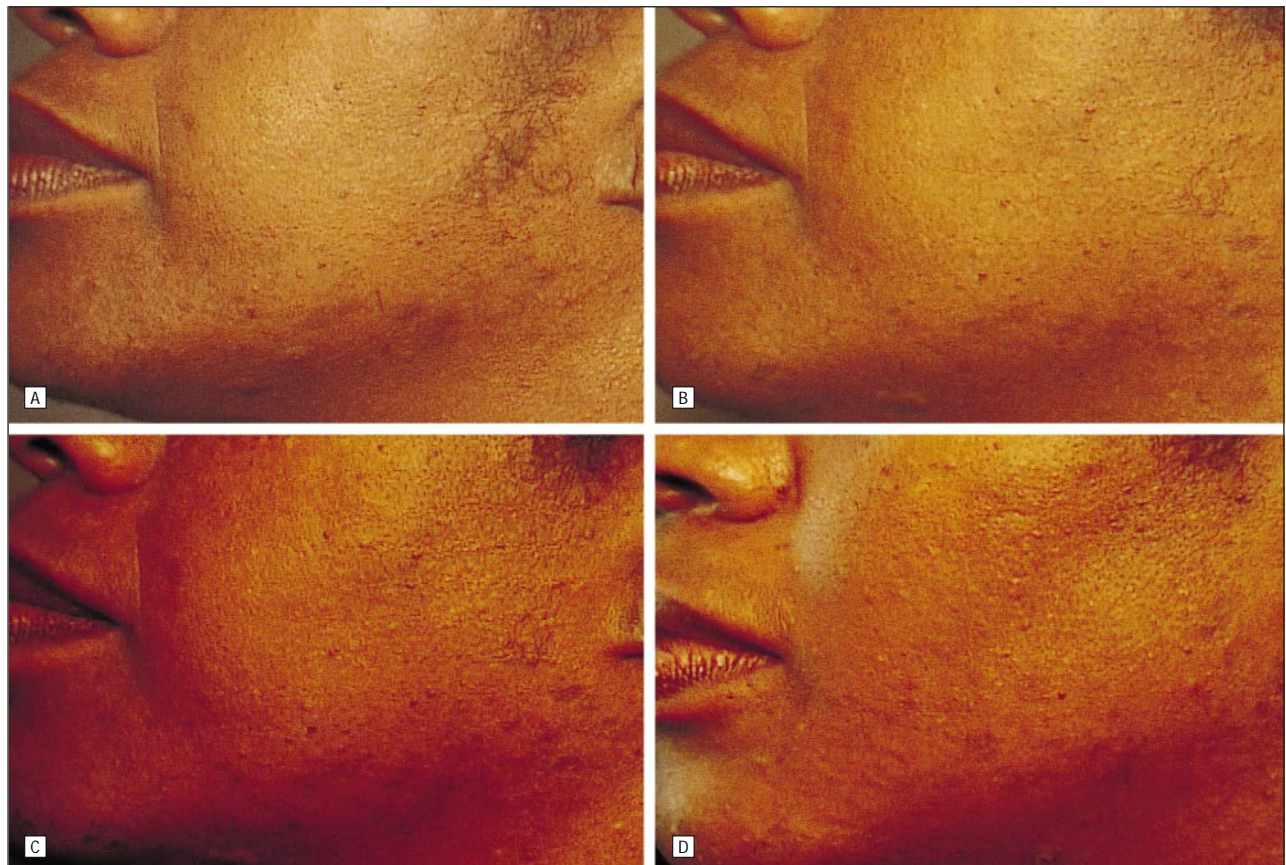


Figure 1. Facial hair before treatment (A) and 1 month after second 1064-nm Nd:YAG (50-millisecond) laser treatment at an average fluence of 40 J/cm² (B). One (C) and 6 (D) months after the third treatment, prolonged hair reduction is seen.

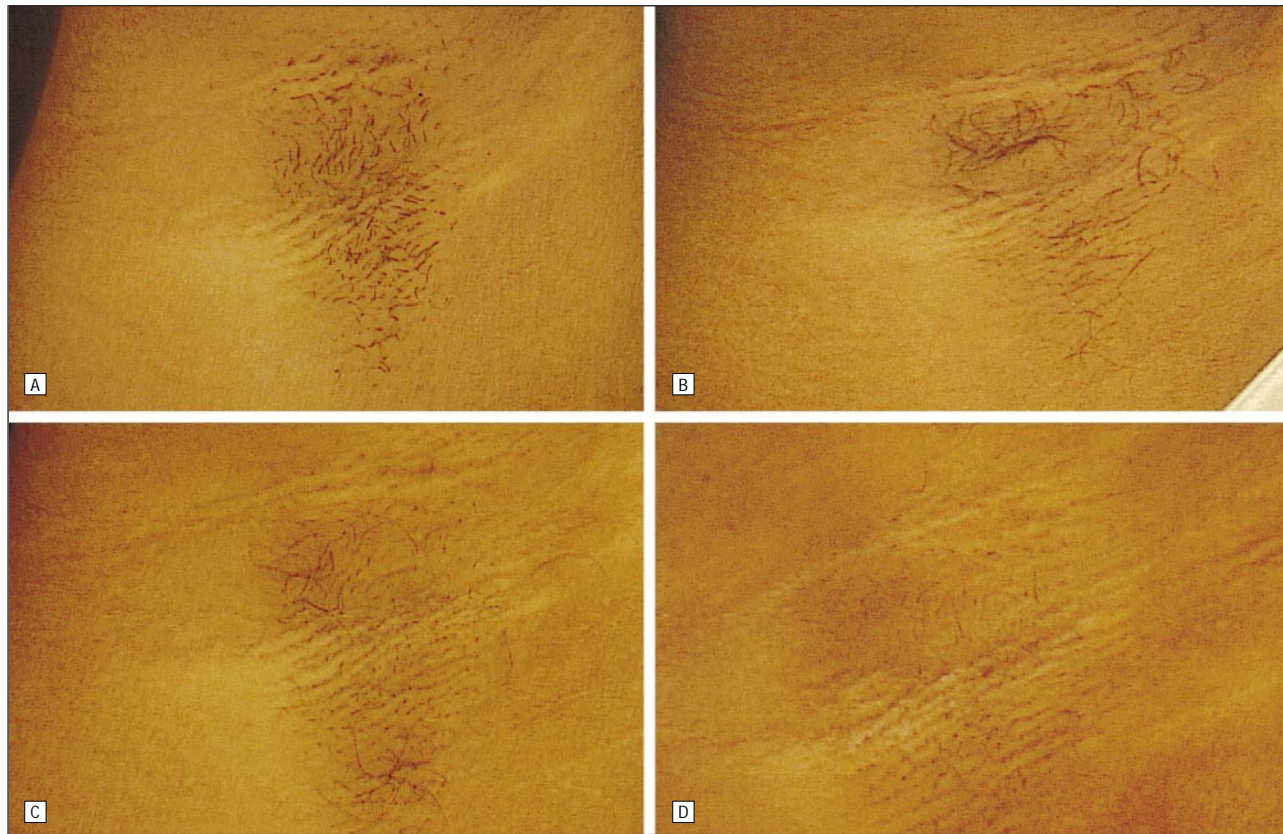


Figure 2. Axillary hair before treatment (A) and 1 month after first 1064-nm Nd:YAG laser treatment at 50 J/cm² (B). Further hair loss was seen 1 month after the second (C) and 6 months after the third (D) treatment session.

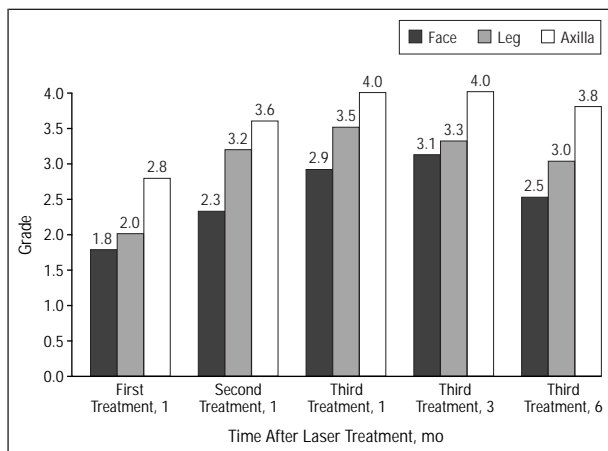


Figure 3. Hair reduction scores. Zero indicates less than 25%; 1, 25% to 50%; 2, 51% to 75%; 3, 76% to 90%; and 4, greater than 90%.

2 tones and dark terminal hair. The relatively high concentration of melanin in hair follicles compared with the epidermis in these patients ensures a high level of efficacy and target-specific energy absorption when pigment-specific lasers are used. In patients with dark skin tones, however, epidermal energy absorption cannot be entirely avoided using any of the aforementioned systems. Thus, the rate of adverse effects is apt to be higher in these patients, leading to the reluctance of many practitioners to avoid treatment of ethnic skin, despite the fact that

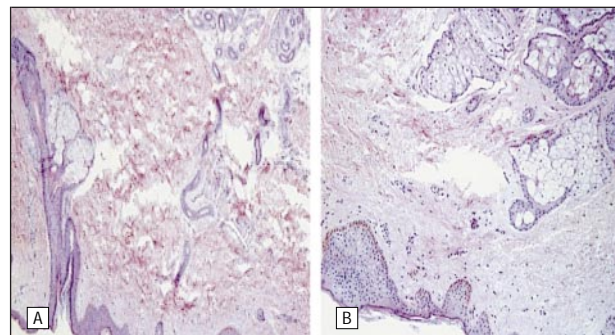


Figure 4. A, Terminal hairs are evident in pigmented skin before laser irradiation. B, Six months after 3 consecutive 1064-nm Nd:YAG laser treatments, pilosebaceous glands and epidermal pigmentation remain intact, but reduced terminal hairs are seen (hematoxylin-eosin, original magnification $\times 10$).

unwanted hair in these patients tends to be darker, thicker, and more cosmetically conspicuous.

The Nd:YAG laser has been of particular interest in the field of laser-assisted hair removal because of its early introduction (in a short-pulsed or Q-switched mode)^{4,15,16} and its known high safety profile.¹⁴ This latter attribute is particularly important when individuals with darker skin tones seek treatment. Previous reports of long-pulsed Nd:YAG laser treatment in patients with dark skin phototypes have been limited by their short postoperative evaluations and/or limited treatment sessions but have substantiated its use in these individuals, nonetheless.^{17,18} Not surprisingly, the longer-pulse (millisecond) Nd:YAG

system has been shown to be more effective in safely removing hair than has the Q-switched (nanosecond) Nd:YAG system, given its closer approximation to the target hair follicle's thermal relaxation time.¹⁹ It is likely that with equivalent fluences, shorter-pulse red and infrared laser systems can also permanently destroy hair follicles, albeit at the expense of the epidermis. The use of lasers with longer pulse durations (≤ 200 milliseconds) permit safe application of higher fluences to patients with darker skin tones, effectively heating the inner and outer root sheaths and the germinative zone without disrupting epidermal melanosomes (which typically respond to short [1-millisecond] pulses).²⁰ Selective bulb and stem cell damage can thus be achieved with pulse durations much greater than the relaxation times of follicles (10-100 milliseconds).

The results of our study support the safe and effective use of the long-pulsed 1064-nm Nd:YAG laser for long-term epilation in darkly pigmented patients. They also provide information about variations in clinical response at different body locations. Specifically, areas characterized by thinner skin (eg, axillae) were more responsive to laser treatment than those with thicker skin (eg, chin and legs), suggesting that skin thickness rather than hair growth cycle influences clinical outcomes. With thick skin, it may become difficult to achieve adequate penetration of energy deep into the follicle. Body location was further highlighted as an important consideration, as transient pigmentary alteration and vesiculation were limited to areas more prone to sun exposure (eg, face and legs, rather than axillae).

CONCLUSIONS

Long-pulsed (50-millisecond) 1064-nm Nd:YAG laser irradiation can achieve rates of hair reduction equivalent to those of other long-pulsed red and infrared laser and intense pulsed-light systems. In addition, the use of a long-pulsed Nd:YAG laser at high fluences can effectively treat patients with darker skin tones while producing few adverse posttreatment sequelae. Sun-protected and thinner axillary skin showed greater clinical response to and fewer adverse effects of laser treatment than did sun-exposed facial and leg skin.

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