Long-Term Hair Removal Using a 3-Millisecond Alexandrite Laser

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Abstract

Background: Laser epilation is now used widely as a clinical alternative to electrolysis for the removal of unwanted hair. All of the laser systems presently being used produce a reliable temporary hair loss by inducing telogen. Most of the published studies use follow-up periods of 6 months or less after the last treatment and cannot address the issue of permanency. Since many patients desire permanent hair loss, there is a need for specific information on the exact benefits and limitations of each particular system.

Objective: The purpose of this study was to assess the degree of hair loss attained by a single treatment with a 3-msec alexandrite laser. A designated period for follow-up was used to address the issue of long-term benefits.

Methods: A single treatment was carried out on 25 study sites with a 3-msec alexandrite laser at 755 nm using fluences of 30 to 50 joules/cm^2. Hair counts were obtained manually by two independent observers marking terminal hairs under magnification. The counts were repeated using photographic images and the average of the four readings taken. The degree of hair loss was calculated at a time after treatment equal to one complete growth cycle for the particular anatomic site. A second measurement was obtained at a time equal to one growth cycle plus 6 months to determine whether any hair loss had remained stable.

Results: The average hair loss at the first follow-up time was 43%, with 60% of sites showing a hair loss of >30%. The hair loss remained stable and the reduction in hair density at both designated times was statistically significant ($p < .05$).

Conclusion: A normal-mode alexandrite laser achieves a long-term alopecia and may result in a permanent loss of terminal hair after one treatment at fluences of 30 to 50 joules/cm^2.

Sommaire

Antécédents : L'épilation au laser est souvent préférée à l'électrolyse pour l'enlèvement des poils superflus. Tous les systèmes laser actuellement utilisés entraînent une perte temporaire et fiable des poils par l'induction d'une phase télogène. La plupart des études publiées font état de périodes de suivi de six mois ou moins après le dernier traitement et n'abordent donc pas d'éventuelle permanence. Or, comme la plupart des patients souhaitent une chute permanente des poils, il faut en savoir plus sur les limites et les avantages exacts de chaque système.

Objectif : Évaluer le degré de la perte de poils obtenu avec un traitement unique au laser alexandrite appliqué pendant 3 millisecondes. Évaluer les avantages du système à long terme après une période de suivi prédéterminée.

Méthode : Application unique sur 25 sites d'un rayonnement laser alexandrite pendant 3 millisecondes avec une longueur d'ondes de 755 nanomètres et fluences de 30 à 50 joules/cm^2. Deux observateurs indépendants ont effectué un dénombrement manuel des poils en marquant les poils adultes à l'aide d'un dispositif de grossissement. Les dénombrements ont été refaits à l'aide d'images photographiques. Il y a eu en moyenne quatre lectures. Le degré de chute des poils a été calculé après le traitement au bout d'une durée équivalant à un cycle de croissance complet pour chaque site anatomique particulier. Une seconde mesure a été prise après un cycle de croissance plus 6 mois, pour déterminer si la perte restait stable.

Résultats : La chute moyenne de poils après la première période de suivi était de 43 %, 60 % des sites présentant une chute de plus de 30 %. La perte est restée stable et la réduction de la densité au bout des deux périodes prédéterminées est statistiquement significative ($p < 0,05$).

Conclusion : Le système laser à alexandrite en mode normal produit une alopécie à long terme et peut entraîner une perte permanente des poils adultes après un seul traitement, compte tenu de fluences de 30 à 50 joules/cm^2.

The removal of unwanted terminal hair may be required in the management of hirsutism, congenital or drug-related hypertrichosis, pseudofolliculitis, transsexual states, and some skin grafts. Some individuals and certain cultures may request elective epilation for hair considered as undesirable. Hirsute patients need a complete endocrine evaluation and diagnosis, particularly when there is evidence of virilization. They may benefit from drugs that modulate androgen metabolism and androgen receptor function. Drug therapy produces gradual but temporary effects, and will not remove unwanted hair from areas that are independent of androgen regulation. Other methods of temporary removal include shaving, waxing, plucking, mechanical epilation devices, and chemical depilatory agents, that require frequent use and are associated with contact dermatitis.[1]

Electrolysis, radiation, and surgical excision of crucial parts of the hair follicle can achieve permanent hair removal.

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Only electrolysis is used as a method of epilation for clinical purposes. It can cause permanent destruction of the hair follicle but carries a definite risk of scarring, particularly from improper technique.[2] There can be considerable variation in the results between therapists, and the rate of permanent hair loss has been reported to be from 15 to 50%.[3] It is a tedious process and is an arduous undertaking for some patients. Even a small zone, such as a female patient with heavy facial hair, could require electrolysis for 26 hours or more over a period of 2 years, with further treatments over an undetermined period of time.[4] Despite its popularity over the past two decades and its use for over 100 years since 1875, there are no controlled trials and little scientific data on which to base efficacy.[5] However, it is a proven method of permanent hair removal and, in capable hands, is a reasonable method of hair removal for small areas or isolated hairs.

Laser epilation is now used extensively as a clinical alternative to electrolysis. There are 15 or more laser or photonic systems currently being used in everyday practice. Published studies confirm that most of these systems produce a reliable, usually complete, but temporary loss of hair by inducing telogen.[6–9] However, laser epilation is generally promoted and offered to patients as a method for "long-term" hair loss, which should mean lasting results equivalent to a significantly extended telogen or permanency. Any assessment of extended telogen or permanency must measure stable hair loss for a designated time *after the last treatment*. This period should be more than the longest telogen or one complete cycle, which varies with body site and gender. Most of the published studies fail to satisfy this criterion and use follow-up periods after the last treatment of 6 months or less. Studies that provide proper data on permanency are starting to appear,[10] but there is a need for specific information on the exact benefits and limitations of each particular system.

The objective of the study was to assess the ability of a single treatment with a normal-mode alexandrite laser to achieve extended telogen or permanent hair removal, using a period of observation longer than one complete hair cycle for the particular body site and respective gender.

Participants and Methods

Twenty-five anatomic sites in 24 adult women with Fitzpatrick's skin type I to IV and black or dark brown hair were selected for the study. The distribution according to body site was axilla (7), pelvic area-bikini or linea (5), moustache (3), thigh (5), calf (2), forearm (1), and buttock (2). The number of treatment sites in each skin type was type I (3), type II (9), type III (12), and type IV (1). Body sites with uniform hair density were selected. For the thigh an area measuring 15 × 25 cm, and for the calf or buttock, an area of 10 × 15 cm was mapped. For all other anatomic areas the entire site was used.

All participants were screened for exclusion criteria of diabetes, photosensitivity, a history of keloid scarring or therapy with retinoids such as Accutane within the past year, current aspirin or iron therapy, and a history of dysplastic nevi or melanoma. Informed consent was obtained and each site was mapped and photographed. A baseline hair count was obtained manually by two independent observers marking terminal hairs under 6× magnification with an apochromatic optical loupe (Nikon). The counts were repeated using photographic images and the average of the four readings taken. Hair density was calculated and recorded as the number of hairs per cm^2. The area was shaved and topical eutectic mixture of local anesthetic (EMLA) cream applied 1 hour before treatment.

The study site was irradiated with fluences of 30 to 50 j/cm^2 using laser pulses placed in an adjacent non-overlapping pattern over the entire test area. A normal-mode, flashlamp-pumped alexandrite laser, operating at 755 nm, was used to conduct the study (GentleLASE™, Candela Corporation, Wayland, MA). Pulse characteristics included a repetition rate of 1 Hz, and pulse duration of 3 msec. Beam delivery was attained through a lens-coupled optical fibre fitted with a 10-mm handpiece. Dynamic cooling of the skin was obtained before each laser pulse with cryogen from an automated device (DCD™), using a spray duration of 50-msec and a 3-msec delay between the end of cryogen spray and the laser pulse.

Serial photography and clinical examination were used to evaluate the subjects at 2 weeks, 1 month, and 3 months to determine hair loss and whether any adverse effects had occurred. A hair count was repeated using the method described previously, at a time after treatment equal to one complete growth cycle for the specific body site (anagen to anagen). The maximum length of the hair cycle was compiled from several sources in the literature[11–13] and the average taken. The designated time for one complete cycle at each site was: moustache – 6 months; axilla – 7 months; forearm – 8 months; pelvic area – 7 months; buttock – 1 year; calf and thigh – 1 year. The third and final hair count was obtained by the same method at a time equal to one cycle plus 6 months. A Student t-test was computed to compare the mean hair counts prior to treatment and at both designated follow-up times.

Results

The average fluence employed was 40 j/cm^2 (range 30–50). The final hair count was measured at an average duration after treatment of 13 months, 11 days (range 12–20 months). The mean baseline and follow-up hair counts per cm^2 were 13.71 (SD = 4.66), 7.1 (SD = 3.77), and 6.35 (SD = 3.58), respectively. At the first follow-up (time = 1 cycle), the average hair loss was 43%, with 60% of sites showing hair loss of >30%. Of the sites 20% (5/25) displayed major hair loss (>80%), and the rate of no response was 8% (2/25). At the second follow-up (time = 1 cycle + 6 months), the average hair loss was 50%. The reduction in hair density at both designated times was statistically significant ($p < .05$).

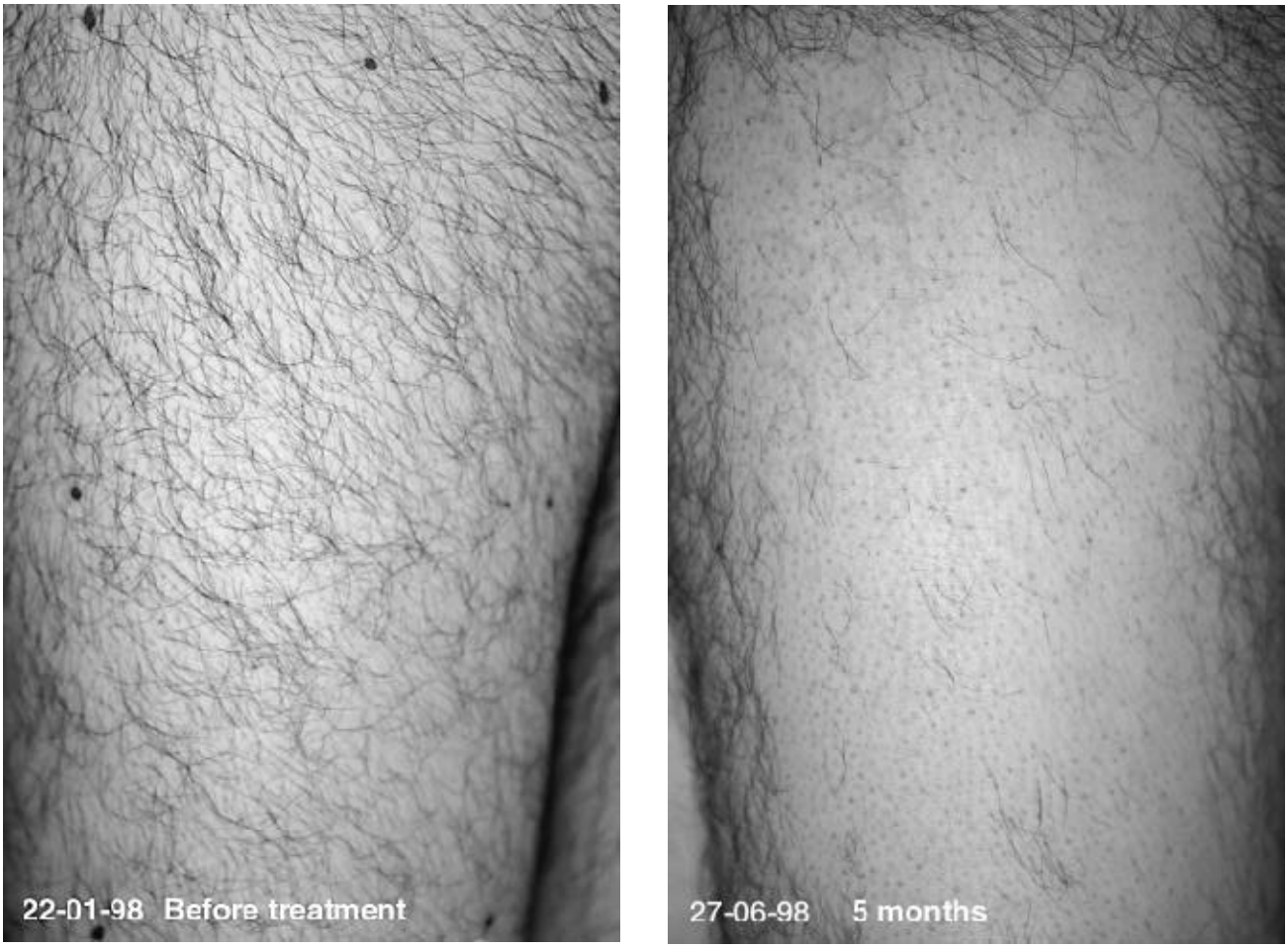

Figure 1 A 27-year-old female participant showing partial regrowth at 5 months after one treatment at 40 j/cm^2.

The regrowth occurring at about 5 months in a typical participant is shown in Fig 1. There has been an 85% hair loss after one treatment at 40 j/cm^2 . The hair loss is sustained at 1 year (one cycle) and persists at 18 months (one cycle+6months) (Fig. 2). The increase in hair loss from 43% to 50% for the entire cohort at the two follow-up times was not significant, but confirms that the reduction remained stable. There was no change between the two measurements for 17 of 25 sites, as is illustrated by the participant in Figure 2. In the other eight sites there was a notable change in the mean hair density between the first and second follow-up that resulted in a further average hair loss of 27%. This difference in the sub-group of eight sites was significant ($p < .05$).

There was one instance of temporary hypopigmentation in a participant with type III skin that resolved by 6 months. Hyperpigmentation occurred in two subjects with skin types III and IV. No treatment was employed and the condition improved, but was still just visible at 1 year after treatment. There was no incidence of atrophic or hypertrophic scarring.

Discussion

The results obtained in this study indicate that a single treatment with a normal-mode alexandrite laser at high fluences can produce a long-term loss of pigmented terminal hair. This finding is similar to that of Dierickx et al.,[10] who reported "permanent" hair loss in 4 of 13 patients after 2 years using a normal-mode ruby laser. They suggested that a 6-month follow-up may be sufficient to assess the final outcome after laser hair removal, because once regrowth had stabilized (usually within 6 months), there was no change in hair counts at 6, 12, and 24 months.

Laser injury shocks anagen hairs into premature telogen and triggers a telogen-to-anagen switch that results in synchronous regrowth after the induced telogen has ended. This argues for duration of hair loss equal to one complete anagen-to-anagen cycle as a basis for defining permanency. It has been proposed that permanent hair reduction be defined as a significant hair loss which is stable for one year[14] or for longer than one complete cycle of the hair follicles at the specific body site.[10,15] However, the reported duration

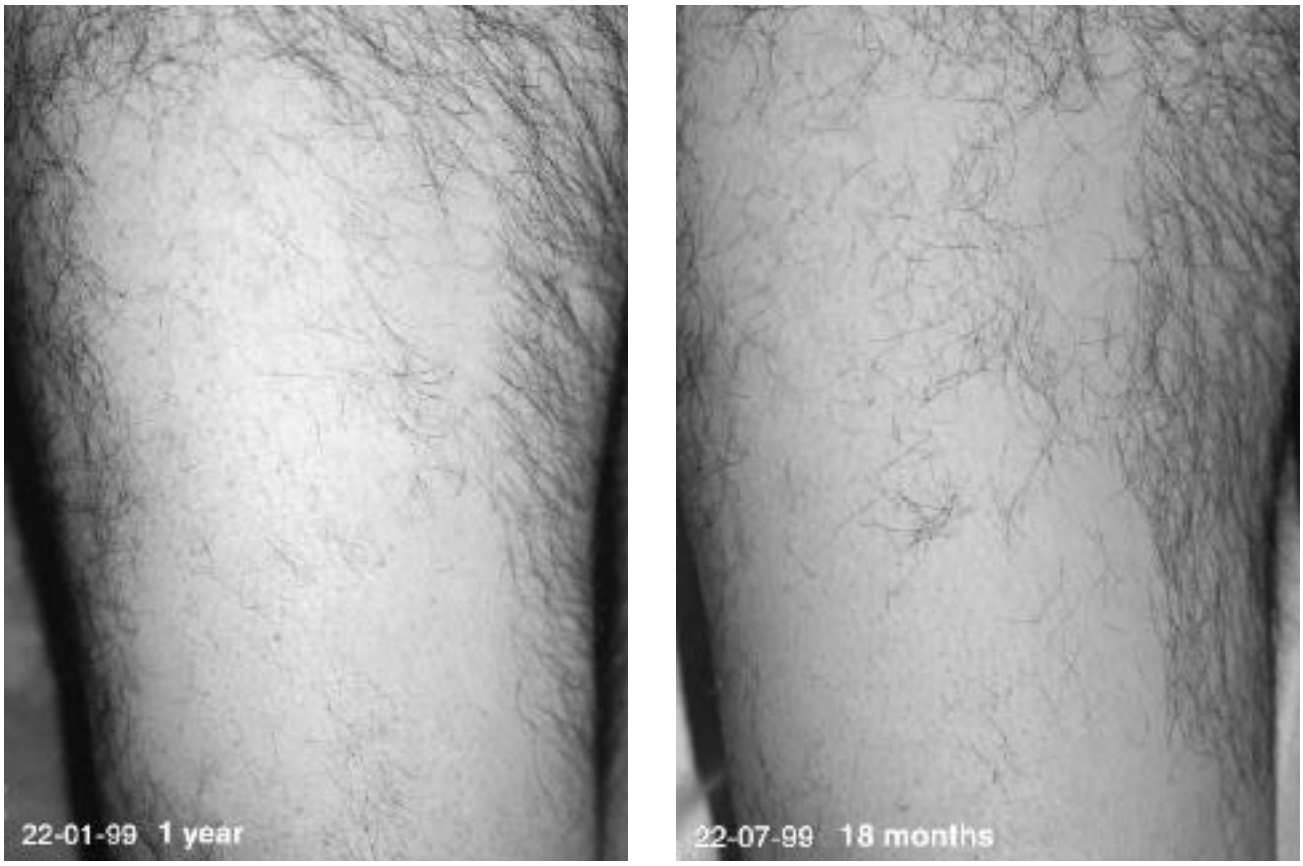

Figure 2 The same participant showing a hair loss of 85%, which remains stable at *1 year* and persists at *18 months* after treatment.

of the hair cycle in various body sites is only an estimate needing further clarification.[5] The methods used to determine the length of telogen and anagen were not standardized and vary significantly between sources.[11–13,16] A final assessment 1 year after the last treatment[14] would satisfy the requirement for one complete cycle for all body sites and encompass the varying estimates from different authors. It would be a simple standard to adopt, but too long for some areas and just adequate for others. Most estimates place the complete cycle for moustache or upper lip at 2 to 6.5 months and for the legs at 6 to 12 months. The standard of one cycle plus 6 months used in this study was also proposed recently by Olsen.[5]

Loss of terminal hairs was explained by histologic findings of miniaturization and conversion to vellus-type follicles,[10] similar to the changes observed in androgenetic alopecia. Stable loss of terminal hair with a histologic picture of conversion to vellus follicles suggests permanency, whereas replacement of terminal follicles by fibrous bands on histology would provide absolute evidence. Biopsies provide information on the type of follicular injury but impose important limitations. A biopsy cannot measure the hair loss in an entire treatment site and prevents any further assessment of the follicles removed. A reasonable alternative is to apply a stringent test of time.[5,14]

The crucial targets for permanent laser destruction of the human hair follicle could include the bulge, hair bulb/dermal papillae area, or other structures in the hair follicle.[5,10,17] The type and pattern of hair loss could vary with the degree, timing, and the particular location of injury within the follicle. Minimal injury induces telogen and temporary hair loss. Lethal injury limited to the bulge and stem cells produce permanent hair loss and miniaturized follicles. A more extensive injury involving the bulb and dermal papilla results in the replacement of the follicle by a fibrous band.

In male-pattern alopecia reconversion is possible in some subjects treated with finasteride. It is unknown whether reconversion to terminal follicles after laser-induced alopecia could occur at some future time. This would be theoretically difficult and should only be possible at androgen-sensitive sites. New terminal hair appearing in androgen-sensitive sites after successful laser epilation could involve new conversion of previously unaffected vellus hairs, which had been spared any laser effects. Follicles disabled by injury to the bulge region and transformed from terminal to vellus hairs could remain resistant to reconversion under androgen stimulus, if the bulge and stem cells play their conceptual role in the regulation of the hair cycle.[17]

Anagen hairs are more sensitive to injury by various agents,[18] and it has been assumed that laser treatment during early anagen is more likely to produce permanent effects.[5,10] Melanin is the target chromophore for laser injury to the follicle. Active melanization and a more superficial bulb make lethal injury to the distal portions of the follicle more likely during early anagen. The bulb and dermal papillae migrate to the deep dermis during late anagen and are more resistant to laser effects. Melanization ceases at catagen and telogen hairs contain little pigment in the bulb to absorb laser energy; however, the bulb and papilla return to a superficial position near the bulge during telogen. Bulge cells are very active in late telogen[17] and would be very susceptible to injury. At any stage of telogen, there is likely to be enough pigment in the hair shaft adjacent to the bulge for adequate absorption of laser energy. There could be lethal injury to the stem cells and the bulge even with low melanogenesis and an unpigmented bulb.

In the participant shown in Figures 1 and 2, there was a substantial hair loss after one treatment. It is evident without tracking individual follicles that both anagen and telogen hairs had to be affected, since 64 to 83% of hairs on the thigh are usually in telogen.[11,13] This observation is supported by a recent study that demonstrated that hair loss was independent of anagen, telogen, or catagen.[19] It now appears that the stem cells near the bulge region are the likely target for permanent laser epilation, since the bulge remains in a fixed position at all phases of the hair cycle.

The results of this study also support the suggestion of Dierickx et al.,[10] that a stable hair loss usually translates into a long-term reduction (extended telogen), which can be claimed as permanent after passing a suitable test of time.[5] The change in average reduction from 43% to 50% for all sites was not statistically significant. Yet the subgroup of eight sites with a significant increase in average hair loss of 27% is notable. This finding suggests that, once hair loss stabilizes after laser injury, there will be no further regrowth in most subjects, but a further loss of hair may develop in some subjects over time. A likely explanation involves follicles in mid-to-late telogen that have been "primed" and already contain a primordial anagen hair below the telogen club hair. The telogen hair is shed after laser injury and the follicle remains in normal or extended telogen. The follicle and the primordial anagen hair in the bulb are preserved, and it ultimately completes one last dystrophic anagen and sheds another telogen hair. A lethal injury to the bulge and stem cells responsible for initiating another anagen prevents any further cycles of terminal hair. Regrowth, followed by new hair loss after a single treatment, supports the concept that effective damage to the bulge also occurs during telogen.

Two participants showed no response as measured by a change in hair density, which does not necessarily mean there was no discernible biologic effect. Hair fibres that regrow after laser treatment generally appear finer and lighter in colour to the naked eye. Changes in hair shaft diameter and colour can occur independently of each other and hair loss, and are influenced by wavelength and pulse duration.[20] Sophisticated and complex methods of analysis are required to quantify these changes. The technology is just emerging and includes digital imaging to measure the calibre and length of hair, and spectrophotometric techniques to detect changes in hair colour.[15,20] This study was not designed to assess these changes. It focused on the issue of permanence, and determined whether there was a measurable reduction in hair count after an appropriate test of time. For this type of study it is reasonable to use a manual count that is performed independently by trained observers, repeated from photographs, and averaged to ensure accuracy.[15] In the issue of permanence, it is the duration of hair reduction that matters more than the actual degree of alopecia. The authors agree that it is unnecessary to include "significant"[10] or any qualifier for the degree of reduction to define permanent hair reduction.[15]

This study provides evidence of permanent hair loss at high fluences (>30 j/cm^2). It has been suggested that the threshold for a growth delay or extended telogen (temporary hair reduction) is low, compared to a higher damage threshold for permanent hair reduction.[21] There is more evidence of a dose-response relationship. For both a diode (800 nm) and a ruby laser (694 nm), hair loss was only temporary at 10 to 20 j/cm^2, more long-term at 20 to 30 j/cm^2, and permanent only at fluences of 30 j/cm^2 or above.[22] The majority of systems in clinical use operate at fluences below 30 j/cm^2. The issue of dose-response relationships and the threshold for temporary versus permanent hair loss needs to be addressed for each system.

It appears that the laser industry and the clinical arena of epilation are being driven by market forces and economic factors, with a minimum of consideration given to evidence-based medicine. The majority of clinical trials and peer-reviewed reports do not address the issues of permanence or specific dose-response relationships. Tope and Hordinsky[15] believe these studies use questionable methods for hair counts or provide no histopathologic data.[7,23–25] Some mix follow-up data from body sites with different hair cycles,[23–25] and most utilize a follow-up period, which is too short, and they provide little statistical analysis.[7,23,25]

There are few comparative data to allow physicians and their patients to make rational choices. Meanwhile the clinical practice of laser epilation appears to have segregated into two distinct groups. Physicians and nonphysicians interested in an "esthetic" practice select lasers that offer a fast method of treatment at lower fluences. Many of these systems base their market appeal on the complete and temporary hair loss from induced telogen attained at low fluences. Rapid treatment times allow for a low price point, which will be attractive to patients. Low fluences pose a lower risk for adverse effects and encourage use by a nonphysician working independently or encourage a physician to delegate the process with little supervision to a nonphysician associate. Physicians involved in a "medical" practice and the more complex task of providing their

patients with permanent hair removal, tend to be more interested in evidence of long-term efficacy. Clinical trials that use valid methods of assessment are required to provide specific information on each and every system. Patients deserve to know the precise benefits and limitations of the particular system to be used in relation to whether their expectation is for temporary or permanent epilation.

Long-term and an apparently permanent hair loss can be obtained after one treatment with a normal-mode alexandrite laser at high fluences. This laser joins a short list of systems for which the hair loss obtained has been subjected to the scrutiny of an appropriate test of time.

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References

1. Richards RN, Marguerite U, Meharg G. Temporary hair removal in patients with hirsutism: a clinical study. Cutis 1990; 45: 199–202.
2. Kligman AM, Peters L. Histologic changes of human hair follicles after electrolysis: a comparison of 2 methods. Cutis 1984; 34:169–176.
3. Wagner RF. Physical methods for the management of hirsutism. Cutis 1990; 45:19–26.
4. Richard RN, McKenzie MA, Meharg GE. Electroepilation (electrolysis) in hirsutism. J Am Acad Dermatol 1986; 15:693–697.
5. Olsen EA. Methods of hair removal. J Am Acad Dermatol 1999; 40:143–154.
6. Grossman MC, Dierickx C, Farinelli W, et al. Damage to hair follicles by normal-mode ruby laser pulses. J Am Acad Dermatol 1996; 35:889–894.
7. Lask G, Elman M, Slatkine M, et al. Laser-assisted hair removal by selective photothermolysis. Dermatol Surg 1997; 15:459–477.
8. Finkel B, Eliezri YD, Waldman A, et al. Pulsed alexandrite laser technology for noninvasive hair removal. J Clin Laser Med Surg 1997; 15:225–229.
9. Smith SR, Tse Y, Adsit SK, et al. Long-term results of hair photoepilation. Lasers Surg Med 1998; 10(Suppl):43.
10. Dierickx CC, Grossman MC, Farinelli WA, et al. Permanent hair removal by normal-mode ruby laser. Arch Dermatol 1998; 134:837–842.
11. Seago SV, Ebling FJ. The hair cycle on the human thigh and upper arm. Br J Dermatol 1985; 113:9–16.
12. Saitoch M, Uzuka M, Sakamoto M. Human hair cycle. J Invest Dermatol 1970; 54:65–81.
13. Trotter M. The life cycles of hair in selected regions of the body. Am J Phys Anthropol 1924; 7:427–437.
14. Richards RN. Electrolysis for permanent hair removal. J Cutan Med Surg 1999; 3:239–240.
15. Tope WD, Hordinsky MK. A hair's breadth closer. Arch Dermatol 1998; 134:867–869.
16. Richards RN, Meharg GE. Electrolysis: observations from 13 years and 140,000 hours of experience. J Am Acad Dermatol 1995; 33:662–666.
17. Cotsarelis G, Sun TT, Lavker RM. Label-retaining cells reside in the bulge area of pilosebaceous unit: implications for follicular stem cells, hair cycle and skin carcinogenesis. Cell 1990; 61: 1329–1337.
18. Braun-Falco O, Heilgemeir GP. The trichogram, structural and functional basis, performance and interpretation. Semin Dermatol 1985; 4:40–52.
19. Dierickx CC, Campos VB, Lin D, et al. Influence of hair growth cycle on efficacy of laser hair removal. Laser Surg Med 1999; 11(Suppl): 21.
20. Lin TD, Dierickx CC, Campos VB, et al. Reduction of regrowing hair shaft size and pigmentation after ruby and diode laser treatment. Laser Surg Med 1999; 11(Suppl):22.
21. Grossman MC, Dierickx C, Farinelli BX, et al. Damage to hair follicles by normal-mode ruby laser pulses. J Am Acad Dermatol 1996; 35:889–894.
22. Campos VB, Dierickx CC, Lin T-YD, et al. Long-term efficacy of normal-mode 694 nm ruby laser and 800 nm diode laser for hair removal. Laser Surg Med 1999; 11(Suppl):22.
23. Goldberg D. Topical suspension-assisted Q-switched Nd:YAG laser hair removal. Dermatol Surg 1997; 23:741–745.
24. Nanni CZ, Alster TS. Optimizing treatment parameters for hair removal using a topical carbon-based solution and 1064 nm Q-switched neodymium:YAG laser energy. Arch Dermatol 1997; 133:1546–1549.
25. Gold MH, Bell MW, Foster TD, et al. Long-term epilation using the EpiLight broad band, intense pulsed light hair removal system. Dermatol Surg 1997; 23:909–913.