

Paradoxical effects of hair removal systems: a review

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Summary

Although a variety of lasers have proven to be clinically effective for long-term hair removal, the use of these lasers has also been associated with undesirable side effects, such as hyper- and hypopigmentation, crusting, erythema, and edema. One notable side effect that seems to be underreported in the literature is the growth of fine dark hair in untreated areas close to the treated ones. This contradictory hypertrichosis is known as the paradoxical effect. In this paper, we review the published reports of the paradoxical effect and offer some possible explanations for this effect. The paradoxical effect has been documented most commonly after the use of induced pulse light and alexandrite lasers. One possible explanation is the activation of dormant hair follicles by suboptimal fluences. Another mechanism may be the synchronization of hair growth cycles by direct light stimulation.

Keywords: hypertrichosis, induced pulse light system, long pulse alexandrite laser, photoepilation

Introduction

A variety of laser systems are commonly used as a safe and efficient treatment for long-term hair removal. The ruby laser (694 nm), alexandrite laser (755 nm), diode laser (810 nm), neodymium:yttrium-aluminum-garnet (Nd:YAG laser (1064 nm), and intense pulse light (IPL [580 and 615 nm]) have all proven to be clinically effective.¹ Although effective, laser treatment is associated with side effects including temporary erythema, perifollicular edema, hypo- and hyperpigmentation, vesicle, and crusting.² Several reports have documented cases of the paradoxical effect after laser treatment, defined as the growth of fine dark hair in untreated areas close to the treated ones.³ Here, we present a review of the paradoxical effect of hair removal systems from cases reported in the literature.

Mechanism of action of laser systems

Two mechanisms of action have been proposed for photoepilation: selective photothermolysis and thermokinetic selectivity.⁴ Selective photothermolysis is based on the principle of selective absorption of energy by components of the hair follicle (Fig. 1). Follicular melanin, found in the hair bulb and outer root sheath zone of the hair follicle, is the target chromophore. Competing chromophores include other melanin-containing components of the skin and other light-absorbing components such as hemoglobin, which may cause injury to the surrounding epidermis. Wavelengths in the red and infrared range (600–1100 nm) are used for photoepilation, and the most effective results are seen when melanization is maximal during the anagen phase of hair growth. Thermokinetic selectivity targets large volume structures such as hair shafts, which are unable to transmit the energy to surrounding structures. By selecting the appropriate pulse length, which is above the calculated thermal relaxation time of the epidermis (3–10 ms) and below the thermal relaxation time of the hair follicles (40–100 ms), thermal damage is concentrated to the target structure, the follicular papilla, germinative

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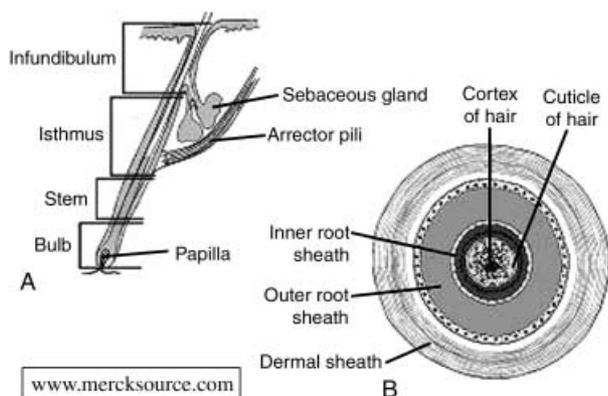


Figure 1 Anatomical structure of a hair follicle.

layer, and bulge area. Both selective photothermolysis and thermokinetic selectivity are involved in photoepilation using the ruby laser, alexandrite laser, Q switched Nd:YAG laser, and IPL.

Spectrum of lasers causing the paradoxical effect

The phenomenon of the paradoxical effect is well known to physicians treating hair removal, but is poorly documented in papers reviewing the effectiveness of laser hair-removal systems. Laser-induced hypertrichosis has been reported most commonly after IPL treatment, but has also been reported after treatment with the alexandrite laser.

Induced pulse light system

Induced pulse light (IPL) systems emit polychromatic light in the wavelength spectrum of 515–1200 nm and its mechanism of action corresponds to selective photothermolysis and thermokinetic selectivity. The wavelength determines both the absorption behavior and penetration depth of the light, so filters may be used to limit its use to a more specific range of wavelengths. IPL is used extensively to treat unwanted hair. Although the exact mechanism of action is undetermined, it has been hypothesized that laser-induced damage to the isthmus and upper stem interferes with the interactions between dermal and epidermal germinative cells, inhibiting or altering the normal hair cycle.

An alternative hypothesis postulates that damage to the hair follicle and hair shaft in the anagen phase causes a long-term interruption in the hair growth cycle.⁵ IPL treatment has resulted in hair reduction of 70–80% for 6 months after treatment.^{1,4,5} In a study by Moreno-Arias *et al.*, the following side effects were reported: transient

erythema (61.2%), transient hyperpigmentation (16.3%), transient hypopigmentation (2%), crusts (18.4%), isolated vesicles (6.1%), superficial burning (2%), persistent local heat sensation (2%), minimal scar (2%), and paradoxical effect (10.2%).² More reports of the paradoxical effect have been published. In a study carried out by Bedewi, 2 out of 210 patients had a paradoxical hair growth after four IPL sessions, roughly 0.01%.¹ In another paper, Moreno-Arias *et al.* studied 49 females with facial hirsutism. A total of five patients (0.1%) were identified with the paradoxical effect.³

Long pulsed alexandrite laser

Scarce data have been published on the paradoxical effect after treatment with the long pulsed alexandrite laser (755 nm). Hair removal by the long pulsed alexandrite laser is mediated by both selective photothermolysis and thermokinetic selectivity. An average fluence of 27.5 J/cm² is used. Three cases noting the paradoxical effect after use of the alexandrite laser have been reported by Alajlan *et al.* It was estimated that laser-induced hypertrichosis occurs in 0.01–1.9% of treated patients.⁶

Discussion

Four responses to light exposure following laser removal of hair may be observed. First, thermal destruction to the hair shaft and not the germinative layer may cause the hair to fall out and regenerate at the next anagen cycle as a normal terminal hair follicle (Fig. 2). Second, the germinative layer in addition to the hair shaft may be thermally damaged, resulting in trichoregulatory dysfunction, telogen-shock response, prolonged telogen dropout, and eventual regrowth of normal hair once the anagen phase has been established again. Third, partial injury to the germinative layer may result in the growth of dystrophic hairs of finer and thinner texture. Fourth, long-term photoepilation, a reduction in the number of hairs over an interval longer than the normal hair cycle of 1 to 3 months, may ensue. This response is mainly caused by light-induced interactions with the primary “bulge” and secondary matrix germinative regions of the pilosebaceous unit. Permanent hair removal is caused by the destruction of the entire germinative areas of the hair follicle (bulge/trichoepithelium/matrix).⁴

Photoepilation by IPL and alexandrite laser systems overall have been safe and efficient means for hair removal, reducing hair growth by 70–80%.¹ Most side effects reported are transient. The paradoxical effect, although rare, is poorly described in reports assessing effectiveness of hair removal systems. This phenomenon should be

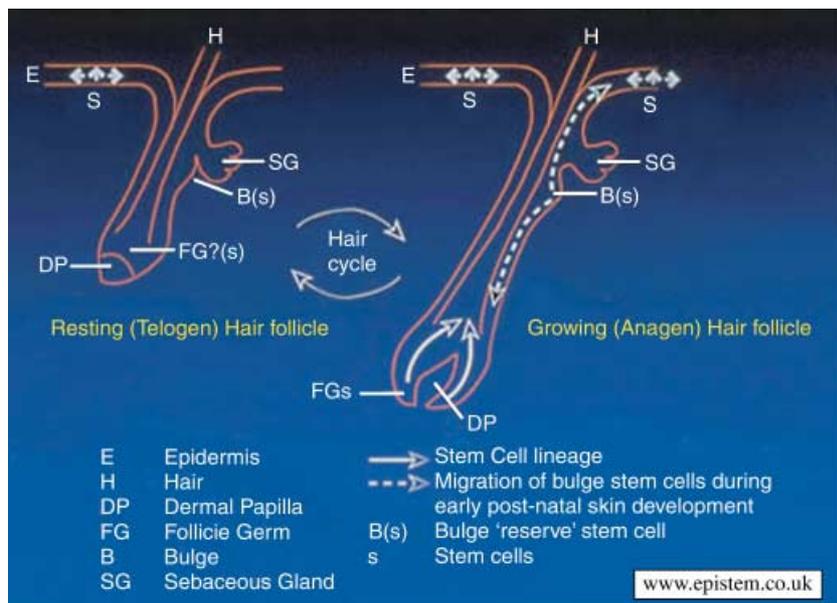


Figure 2 Phases of hair follicle growth.

addressed more frequently as an unsatisfactory side effect of hair removal.

Two explanations have been offered.³ First, suboptimal fluences may activate dormant hair follicles in surrounding untreated areas, leading to hair growth. Second, direct light synchronized hair growth cycles by first damaging exposed anagen follicles. Next, a new follicular rhythm in unexposed dormant hair follicles in untreated areas close to the treated ones is established. Since hair growth in surrounding areas is now synchronized, overall hair density appears to be greater compared to previous asynchronous hair growth. In a study reporting hypertrichosis after alexandrite laser treatment, the average fluence used (27.5 J/cm²) is at the lower effective standard ranges in the literature, lending support to the proposed explanation of activation of dormant hair follicles by suboptimal fluences. Finally, dark skin (types III–V) may be a risk factor for the paradoxical effect.⁶ A trend for the paradoxical effect to occur in darker skin phototypes (IV) compared to unaffected subjects was observed.

Conclusion

Although laser hair removal treatments are generally effective, clinical challenges still exist. An optimal fluence

setting needs to be found that is not low enough to stimulate hair growth and not high enough to cause burning, erythema, and other unwanted side effects. Furthermore, additional studies are needed to define the risk factors for laser-induced hypertrichosis, such as skin type, sex, and location of treatment, to provide better clinical outcomes for patients.

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