Epilation Today: Physiology of the Hair Follicle and Clinical Photo-Epilation

Nathalie Mandt,* Agneta Troilius,† and Michael Drosner‡
*Clinical Research Center for Hair and Skin Physiology, Department of Dermatology and Allergy, Charité University Medicine Berlin, Berlin, Germany; †Laser section, Department of Dermatology, University Hospital, Malmö, Sweden; ‡Cutaris Center, Dermatology-Phlebology-Laser Medicine, Munich, Germany

Despite the variations of length and type of hair (vellus or terminal), the growth of human hair in all body sites is cyclic. Phases of active hair growth, or anagen, are separated by periods of quiescence, or telogen. The duration of both phases varies greatly depending on the body site. Whether hairs are in anagen/telogen at the time of hair removal is important because only anagen hairs are particularly sensible to physical insults. Photo-epilation is a technique for long-term removal of unwanted hair by thermal destruction of the hair follicle and its reproductive system (stems cells). As melanin is the main chromophor existing in hair follicles the corresponding wavelength spectrum would range from ultraviolet up to infrared light. Furthermore longer wavelengths are preferred as the cromophor lies deep in the skin and the penetration of light is increasing with the wavelength. Thus, in the range of 600–1100 nm melanin absorption may be used for selective photothermolysis of hair follicles. Yet to be resolved questions for permanent destruction are the location of the key follicular target and the possible influence of the hair growth cycle on photothermolysis-induced hair removal. An overview on the individual physiology of the hair follicle is given to discuss the latest strategies for photo-epilation.

Key words: hair follicle/physiology/epilation/removal/laser/treatment
J Investig Dermatol Symp Proc 10:271–274, 2005

Laser or flash lamp-assisted hair removal is a well-tolerated and relatively effective option for patients who desire permanent reduction of hair growth. Although laser and light sources are very popular because of their non-invasive nature and the speed at which they operate, practitioners and patients have to be cautious to prevent (permanent) adverse effects instead of permanent hair reduction. To achieve better results in long-term epilation, it is preferable to include the knowledge of hair physiology into the strategy of photo-epilation. Therefore, an update of physiology is discussed first before guidelines for photo-epilation will be presented.

Structure and Function

Hair can be classified according to its texture and length. In adults, there are terminal and vellus hairs, and a whole range of intermediate types. Hairs tend to grow in Meijières trio groups, but each individual hair follicle disposes of an intrinsic cycle regulation. Thus, the hairs within this group grow in an asynchronous manner and may not be recognized before treatment (Blume *et al*, 1991). This fact should be taken into consideration during photo-epilation.

Anatomically, the hair follicle is divided into two major units: the supraglandular region or the infundibulum and the infraglandular region, separated at the isthmus region, which encompasses the area between the entrance of the sebaceous duct. The infundibulum includes the region from the hair follicle orifice to the sebaceous duct. The infraglandular segment includes the bulge region and the hair bulb. Functionally, a permanent and a non-permanent (transient) portion of the hair follicle exist. The bulb of terminal, anagen hair follicles is usually located in the subcutaneous fat, which, depending on the thickness of the skin depth, can vary from 2 to 7 mm (Ross *et al*, 1999).

Hair Cycle

The hair growth cycle is characterized by cycling periods of growth and rest, termed, respectively, as anagen and catagen/telogen. The duration of the anagen and telogen periods differs from one part of the body to another, as attested by the different lengths of hair in different parts of the human integument. The length of hair in any region is primarily a function of the relative durations of anagen and telogen.

Hair Follicle Cells

The hair follicle is a complex skin appendage organ composed of epithelial, mesenchymal, and neuroectodermal components following cyclical changes of growing, controlled by a complex network of cell–cell signalling (Mandt *et al*, 2002). The permanent portion of the hair follicle is composed of the bulge and persists through all phases of the hair cycle and is supposed to be the region where the follicular stem cells are located. The "bulge hypothesis" suggests that control of the hair cycle is linked to a complex interaction between the bulge and the dermal papilla, lo-

cated in the transient portion at the hair bulb (Cotsarelis *et al*, 1990). The hair bulb is composed of matrix cells, interspersed by melanocytes, which encloses the dermal papilla with its mesenchymal cells and vascular network. The germinative matrix cells are believed to be another source of stem cells, closely interacting with the dermal papilla (Jahoda and Reynolds, 2000). Recently, stem cells of melanocyte lineage have been identified in the lower portion of mouse hair follicles throughout the hair cycle (Nishimura *et al*, 2002).

Follicular Melanocytes

Within the human hair follicle, two types of melanocytes are found: pigmented and dendritic melanocytes around the infundibulum and the bulbar region, and amelanotic, non-dendritic melanocytes in the outer root sheath (ORS) in the bulge region and the lower part of the hair follicle. Melanocytes located in the matrix of the bulb produce melanin only during the anagen phase II–VI, transferring melanin granules to hair keratinocytes (Ross *et al*, 1999). Distinct types of melanosomes exist in hair of different colors: the brownish-black eumelanin and the reddish pheomelanin. The absorbance at 694 nm is 30 times lower for pheomelanin compared with eumelanin. Pheomelanin absorption is very low at wavelengths from 750 to 800 nm (Ross *et al*, 1999).

Vascular Network

In the anagen phase, the human hair follicle is highly vascularized, whereas during the catagen stage, capillaries collapse and disappear. The changes observed in vascularization during hair cycle appear to be closely related to hair cycle regulation processes. Blood vessel supply, a prerequisite for normal cell growth and development, seems to be of fundamental importance in the active processes of hair cycling (Godynicki *et al*, 1997).

Key Targets

Yet to be resolved questions for permanent destruction are the location of the key follicular target and the possible influence of the hair growth cycle on photothermolysis-induced hair removal. For many years, it has been assumed that hair stem cells could only be found in the matrix area of the bulb; however, recent evidence suggests that follicular stem cells and melanocytic stem cells are located in the bulge and the ORS. Both bulge and bulb could be important targets for permanent hair follicle destruction. In addition, the dermal papilla closely interacting via cell–cell signaling with its surrounding matrix cells could be of importance. Destruction of the vascular network may lead to catagen/telogen formation, indicating its role as a further key target in photo-epilation.

Actual Knowledge of Photo-Epilation

Photo-epilation is a technique for long-term removal of unwanted hair by thermal destruction of the hair follicle and its reproductive system (stems cells). The heat is caused by selective absorption of electromagnetic radiation emitted by different light sources, mainly by lasers and flash lamps (high-intensity incoherent and multichromatic pulsed light) or by combinations with radio frequency. As melanin is the main chromophor existing in hair follicles, the corresponding wavelength spectrum would range from ultra violet up to infrared light. Furthermore, longer wavelengths are preferred as the chromophor lies deep in the skin and the penetration of light increases with the wavelength. Thus, in the range of 600–1100 nm, melanin absorption may be used for selective photothermolysis of hair follicles. The following light sources have proven successful for a variety of skin types: ruby laser (695 nm), alexandrite laser (755 nm), diode laser (800 nm), neodymium:yttrium aluminum garnet (Nd:YAG) laser (1.064 nm), and different flash lamps ($=$ intense pulsed light, I^2PL or IPL, e.g., Ellipse 600–950 nm (Danish Dermatologic Development A/S, Horsholm, Denmark) or Quantum 590–1200 nm (Laser Quantum Ltd., Stockport, Cheshire, United Kingdom)). In IPL sources, the selection of the suitable range of wavelength is made by placing appropriate filters (cut-off filters) and water between the light source and the crystal leading the light to the skin surface. In I^2PL systems, the water will absorb the infrared wavelength, and cut-off filters are used to eliminate the short wavelength.

Regardless of the type of laser used, multiple treatments (three to eight) performed every 6–8 wk are necessary to achieve satisfactory results. Average rates of long-term hair reduction are reported between 70% and 90% at a minimum of 6 mo (Dierickx, 1999). The efficiency of the different light sources is comparable, except in the Nd:YAG laser, which is less effective in light-skinned patients but is the treatment of choice, and more safe in subjects with darker skin (Fitzpatrick skin type IV–VI), especially with pseudofolliculitis barbae (Weaver and Sagaral, 2003). Patients with dark hair and light skin are ideal candidates for photo-epilation. Often, regrowing hairs are thinner and lighter in color. None of the lasers mentioned, however, are effective in light or white hair. It is generally believed that hair follicles are more responsive to treatment while they are in the growing (anagen) phase. So far, there is no most favorable treatment site known; however, the chin area shows the weakest clearance rate and the back might have a high recurrence rate in some individuals (e.g., Mediterraneans). Adverse effects after photo-epilation are reported to occur in 2.7%. They include erythema and perifollicular edema, which are common, as well as crusting, vesiculation, hypopigmentation, and hyperpigmentation (depending on skin color and other factors leading to excess heat production). Most complications are generally temporary. After severe burns, hypopigmentation and scar formation might be permanent adverse effects. Thus, it is important to avoid sun tanning or the use of sun-less tanners prior to treatment.

Photo-epilation has become a common technique for hair growth control. But despite considerable technical advances in this field, these devices still have the potential to cause injury when used improperly. It is important to follow precise treatment guidelines in order to achieve safe and optimal results. The following treatment and safety guidelines are provided to assist the practitioner in the use of

these devices. A detailed version of these guidelines are published in the Journal of Medical Laser Application (Drosner *et al*, 2001).

Treatment and Safety Guidelines (Headlines and Enumeration)

Indication Detailed medical history and examination; primarily cosmetic reasons hypertrichosis (mainly genetic or ethnic, also secondary to endocrine disturbances, malnutrition, porphyria, medication); hirsutism (idiopathic or secondary to endocrine disorders, medication, virilizing tumors, chronic (pseudo-)folliculitis) (Kvedar *et al*, 1985).

Patient selection An ideal patient has realistic expectations.

Patient information and consent Oral and written information; multiple treatments; partial; or complete hair regrowth.

Pre-laser treatment care Pale skin color; no plucking, waxing, or electrolysis before photo-epilation; cut hair down to skin surface; remove make-up; mark the area with a white eye liner; treatment grid; painful procedure; anesthesia not recommended in our opinion, because pain is the best early warning system to prevent side effects; check photo-epilation equipment.

Choice of the right instrument Advantages of contact and non-contact method; pressure on the skin surface; Nd:YAG laser less effective, but more safe in dark skin; ruby laser connected with higher risk of side-effects, also least penetrating (Grossman *et al*, 1996).

Epilation treatment Shorter wavelengths are more effective in light brown and thin hair; longer wavelengths are deeper penetrating and safer to use in darker pigmented skin types; the larger the spot size, the deeper the light penetratation into the skin; the pulse width should be adapted to the grade of skin pigmentation and to the content of pigment of the hair; higher fluences result in a higher degree of hair reduction; safety goggles.

Treatment endpoints and initial signs of adverse effects Widespread erythema; perifollicular edema; gray or pale white discoloration of the epidermis; test spot observed for at least 5 min.

Cooling Pre-, parallel, and post-cooling; functionally adequate: contact cooling, cold air ventilation (Drosner and Stangl, 2001), and dynamic cooling devices (DCD).

Post-laser treatment care Cooling; topical corticosteroids; sun screen (SPF 60).

Follow-up Multiple treatments (3–8) performed every 6–8 wk.

Physician qualifications Completed residency training in an appropriate specialty; knowledge of basic laser physics; laser–tissue interaction and laser safety; training courses (Dover *et al*, 1999).

Delegation of photo-epilation Staff training at least during 1 y.

Adverse effects and safety precautions Adverse effects: prolonged erythema, edema, swelling, blister, crust, or scar formation, pigmentary changes, growing of thinner or paler hair, induction of hair growth; eye protection with metal lenses; pigmented nevi should not be treated; methods to reduce the incidence of adverse effects: longer pulse durations in darker skin, low-dose treatment (Drosner *et al*, 2001); caution with hypertrophic scarring or keloids.

Pregnancy No photo-epilation during pregnancy.

Disclaimer This report reflects the best data available at the time the report was prepared, but caution should be exercised in interpreting the data; the results of future studies may require alteration of these recommendations; ideal treatment parameters must be individualized for each patient and with each device; adherence to these guidelines will not ensure successful and safe treatment in every situation; the ultimate judgment regarding the propriety of any specific procedure must be made by the physician in light of all the circumstances presented by the individual patient.

Supporting evidence These guidelines of care for photo-epilation are based on the experience of the members of the European society of laser in dermatology (ESLD), and review articles in the literature (Finkel *et al*, 1997; Wheeland, 1997; Dierickx *et al*, 1999; Garcia *et al*, 2000; Hobbs *et al*, 2000; Liew, 2002).

DOI: 10.1111/j.1087-0024.2005.10116.x

Manuscript received September 20, 2004; revised April 04, 2005; accepted for publication April 29, 2005

Address correspondence to: Nathalie Mandt, Clinical Research Center for Hair and Skin Physiology, Department of Dermatology and Allergy, Charité University Medicine Berlin, Berlin, Germany. Email: nathalie.mandt@charite.de

References

Blume U, Ferracin J, Verschoore M, Czernielewski JM, Schaefer H: Physiology of the vellus hair follicle: Hair growth and sebum excretion. Br J Dermatol 124:21–28, 1991

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 61:1329–1337, 1990

Dierickx CC, Alora MB, Dover JS: A clinical overview of hair removal using lasers and light sources. Dermatol Clin 17:357–366, 1999

Dover JS, Arndt KA, Dinehart SM, Fitzpatrick RE, Gonzalez E: Guidelines of care for laser surgery. J Am Acad Dermatol 41:484–495, 1999

Drosner M, Stangl S: Does cooling with cold air influence the efficiency of foto epilation? J Med Laser Appl 16:161, 2001

Drosner M, Stangl S, Hertenberger B, Klimek H, Pettke-Rank C: Low dose epilation by alexandrite laser: A dose response study. J Med Laser Appl 16:293–298, 2001

Finkel B, Eliezri YD, Waldmann A, *et al*: Alexandrite laser technology for non-invasive hair removal. J Clin Laser Med Surg 15:225–229, 1997

Garcia C, Alamoudi H, Nakib M, *et al*: Alexandrite laser hair removal is safe for Fitzpatrick skin types IV–VI. Dermatol Surg 26:130–134, 2000

Godynicki S, Gasse H, Schwarz R, Wenthe M: Nutritional and functional blood vessels of anagen and telogen vibrissal follicles in the cat. Acta Anat (Basel) 160:83–87, 1997

Grossman MC, Dierickx CC, Farinelli W, Flotte T, Anderson RR: Damage to hair follicles by normal-mode ruby laser pulses. J Am Acad Dermatol 35:889–894, 1996

Hobbs L, Ort R, Dover JS: Synopsis of laser assisted hair removal systems. Skin Ther Letter 5:1–5, 2000

Jahoda C, Reynolds A: Skin stem cells—a hairy issue. Nat Med 6:1095–1097, 2000

Kvedar JC, Gibon M, Krusinski PA: Hirsutism: Evaluation and treatment. J Am Acad Dermatol 12:215–225, 1985

Liew SH: Laser hair removal. Guidelines for management. Am J Clin Dermatol 3:107–115, 2002

Mandt N, Geilen CC, Wrobel A, Gelber A, Kamp H, Orfanos CE, Blume-Peytavi U: Interleukin-4 induces apoptosis in cultured human follicular keratinocytes, but not in dermal papilla cells. Eur J Dermatol 12:432–438, 2002

Nishimura EK, Jordan SA, Oshima H, *et al*: Dominant role of the niche in melanocyte stem-cell fate determination. Nature 416:854–860, 2002

Ross EV, Ladin Z, Kreindel M, Dierickx C: Theoretical considerations in laser hair removal. Dermatol Clin 17:333–355, 1999

Weaver SM III, Sagaral EC: Treatment of pseudofolliculitis barbae using the long-pulse Nd:YAG laser on skin types V and VI. Dermatol Surg 29:1187–1191, 2003

Wheeland RG: Laser-assisted hair removal. Dermatol Clin 19:469–477, 1997