Journal of the
American Academy of
DERMATOLOGY
VOLUME 40 NUMBER 2 PART 1 FEBRUARY 1999

CONTINUING MEDICAL EDUCATION

Methods of hair removal

Elise A. Olsen, MD *Durham, North Carolina*

The methods of hair removal vary between simple inexpensive means of home treatment (shaving, plucking, depilatories) to expensive and potentially time-consuming means used by paraprofessionals, nurses, and/or physicians (electrolysis, lasers, x-ray). The ways in which these different methods induce hair removal, the duration of such removal, and the nuances between devices within the same category of methods are discussed. (J Am Acad Dermatol 1999;40:143-55.)

Learning objective: At the completion of this learning activity, participants should be cognizant of the different control mechanisms for hair growth and how the different means of hair removal affect these. Readers will also become familiar with the different types of electrolysis and lasers currently used for hair removal and the advantages and disadvantages of each.

Current medical therapy with drugs that block or modify some portions of the androgen cascade or androgen receptor binding may halt or even cause regression of hirsutism but will have no effect on non-androgen-dependent unwanted hair. Moreover, medical treatment is only effective while the medication is being taken and will not totally eliminate the presence of visible pigmented hairs. To accomplish the latter, one must remove all the hair shafts in a given area; for this to be permanent, critical parts of the follicular apparatus must be destroyed.

In addition to hirsutism, which requires a medical evaluation first to rule out an adrenal, ovarian, or pituitary problem, other medical indications for hair removal include congenital or drug-induced hypertrichosis, pseudofolliculitis, hair from grafted donor sites, and men undergoing sex change operations. Obviously, patients may also designate other areas of hair growth as cosmetically undesirable (eg, "bikini" areas in women and "excessive" back hair in men). Unwanted hair can be dealt with in several different ways with either a temporary or permanent intent. Types of hair removal acknowledged to be temporary include shaving, use of abrasives, plucking, depilatories, and certainly types of x-ray therapy. Laser hair removal and photodynamic therapy are treatments that generally lead to temporary hair removal but for which long-term data regarding permanency are only now beginning to appear. Those types of hair removal that claim to be permanent must first pass the test of time, a measure that varies between body sites and genders. Methods of hair removal that have been proven to be permanent are certain forms of electrolysis, x-ray, or surgical excision of key portions of the follicle. This article attempts to inform the reader of the available means of hair removal and mechanisms involved in hair growth that must be considered in planning a strategy of permanent removal of hair.

From the Division of Dermatology, Duke University Medical Center.
Reprint requests: Elise A. Olsen, MD, Division of Dermatology, Director, Duke Dermatopharmacology Study Center, Duke University Medical Center, Box 3294, Durham, NC 27710.

0190-9622/99/$8.00 + 0 **16/2/95483**

OVERVIEW

Despite the variations in length and type of hair (vellus or terminal), the growth of human hair in all body sites is cyclic. Phases of active hair

Journal of the American Academy of Dermatology
February 1999

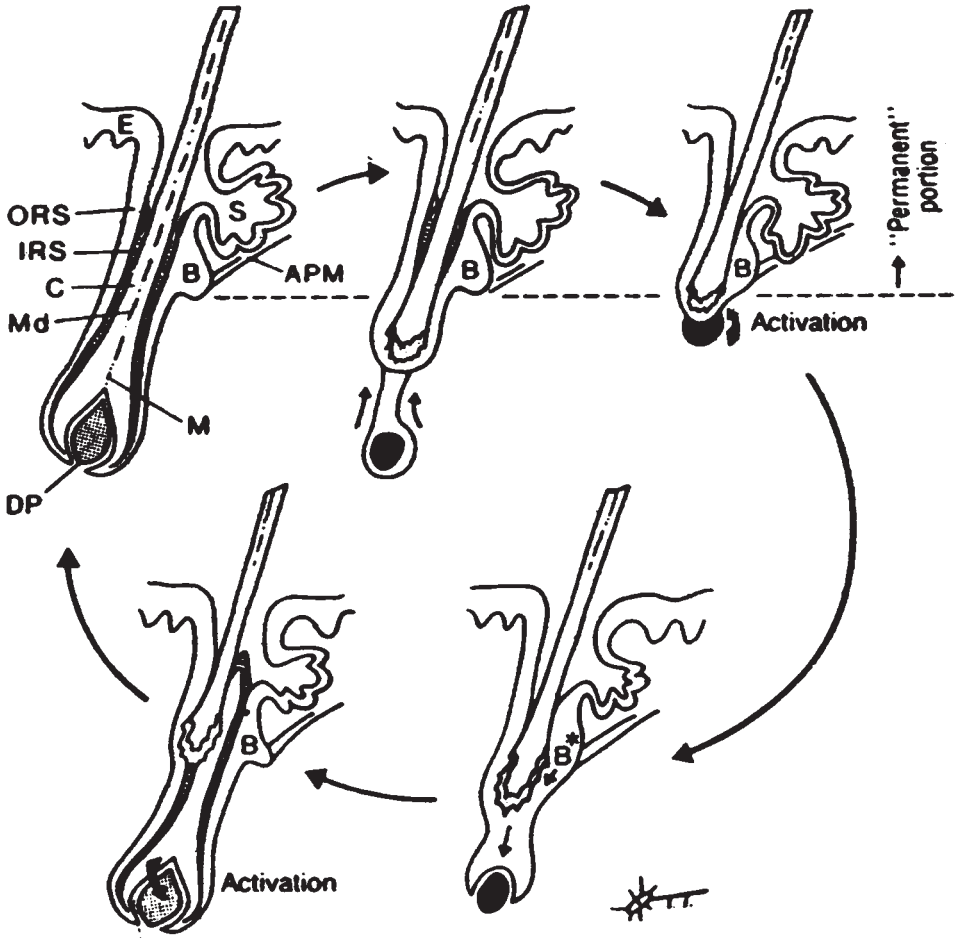

Fig 1. The hair cycle. Illustrated are different phases of the hair cycle including anagen, catagen, and telogen. Different structures are labeled including arrector pili muscle *(APM)*, bulge *(B)*, cortex *(C)*, dermal papilla *(DP)*, epidermis *(E)*, inner root sheath *(IRS)*, matrix *(M)*, medulla *(Md)*, outer root sheath *(ORS)*, and sebaceous gland *(S)*. *B* and *B** denote quiescent and activated bulge cells, respectively. Follicular structures above the *dotted line* form the permanent portion of the follicle; keratinocytes below the bulge degenerate during catagen and telogen. (From Cotsarelis G, Sun Tung-Tien, Lavker RM. Cell 1990;61:1333. Reprinted with permission.)

growth, or anagen, are separated by periods of quiescence, or telogen.[1] During anagen, the epithelium-derived hair bulb partially encases the mesoderm-derived component, the dermal papillae (Fig 1). In the lower hair bulb, melanocytes actively transfer melanin to the dividing population of matrix cells. As the matrix cells move more superficially in the hair bulb, they differentiate into elements of the hair shaft and inner and outer root sheaths; the latter serve to firmly anchor the hair shaft. At the end of anagen, lower matrix keratinocytes cease proliferation and undergo terminal differentiation resulting in involution of the lower follicle. Melanization ceases immediately before the conclusion of anagen and the follicular bulb moves up superficially in the dermis. The connective tissue sheath surrounding the hair shaft and root sheaths contracts, pulling the dermal papillae cells contained therein toward the bottom of the regressing follicle. The inner root sheath dissipates and the outer root sheath terminally differentiates at the level of the isthmus (the area between the sebaceous duct and the insertion of the arrector pili muscle), thus leading to tenuous anchoring of the telogen hair shaft to the follicular wall. After a period that appears relatively fixed for a given body area,

the final shedding of the telogen hair generally signals a new period of anagen.

The duration of anagen varies greatly depending on age, season, gender, body site, hormones, and underlying genetic susceptibilities.[2-12] In regard to vertex scalp hair, regardless of the presence or absence of androgenetic alopecia, there is not only a decrease in the duration of anagen with age but there may be a prolongation of the latency period between the loss of a telogen hair and new anagen growth.[2] There is a seasonal change in the percentage of scalp hair in anagen with a peak in the spring (in the northern hemisphere) and trough in the late summer and early fall coincident with increased shedding.[4] That gender and body area are other factors in affecting duration of anagen is shown by the 54-day anagen in the thigh hair of men versus the 22-day anagen in women,[3] compared with the several year duration of anagen in the scalp hair of either sex. The duration of anagen and telogen and percentage of telogen in different body areas as determined by various methods during the past 70 years or more is given in Table I. These data are inexact, but nonetheless serve to emphasize that one cannot group hairs from different body areas when discussing effects on hair growth. Moreover, it is imperative to become familiar with the specifics of anagen and telogen in the nonscalp area where hair removal is to be carried out; this allows anticipation of the lag time to regrowth after temporary hair removal and the span of time necessary to effect permanent removal (ie, the complete cycle length).

The rate of hair growth is also related to the body area involved, being fastest for the longest growing hairs (chin, 0.38 mm/day; scalp, 0.35 mm/day) and slower for short hairs (axilla, 0.30 mm/day; thigh, 0.20 mm/day; eyebrows, 0.16 mm/day).[8] The rate of growth may also be affected by age and hormonal status; Trotter[11] reported leg hair growth at 1.42 mm/wk for girls 13 to 14 years old and 1.85 mm/wk for women 40 to 45 years old.

Whether hairs are in anagen or telogen at the time of hair removal is important because only anagen hairs are particularly sensitive to chemical, cytostatic, physical, hormonal, infectious, or inflammatory insults.[12] In response to various types of damage to the anagen hair, there is disturbance of the metabolism of the mitotically active matrix cells, with the pattern of reaction dependent on the duration and intensity of the insult and the duration of the reaction dependent on the type of insult. Under pathologic conditions, 3 reaction patterns of anagen follicles are observed: premature termination of anagen and entrance into telogen, the usual response to slow minor damage; transition from normal anagen to dystrophic anagen; and acute matrix degeneration.

The follicular location of the insult is also important in determining the outcome. Earlier theories on recapitulation of the anagen cycle focused on the necessary preservation of the hair matrix (the putative site of follicular stem cells) and the contiguous dermal papillae.[16] However, we know from the elegant transection experiments of Oliver[17,18] on rat vibrissae that if the dermal papillae and not more than the lower one third of the follicle is removed, the hair follicle can regenerate. Oliver also found that when lengths of the lower third of the vibrissae follicle wall, but not lengths of the upper two thirds of the follicle wall, were transplanted into ear skin, whiskers were again produced.[19] From these experiments, it was clear that the outer root sheath and the adherent mesenchymal layer from the lower follicle were, in the absence of a matrix and dermal papilla, the essential elements in the regeneration of the hair follicle. Additional studies then addressed the issue of whether it was the outer root sheath cells in the upper third of the follicle that were incapable of supporting whisker growth or of stimulating papilla formation or whether the mesenchymal cells at this level were incompetent to form a dermal

Table I. Hair cycle

	Duration*		
Body area	**Anagen**	**Telogen (mo)**	**% Telogen**
Scalp	2-6 y[10]	3-4[10]	10-15[12-14]
Eyelashes	1-1.5 mo[15]		
Eyebrows	1-2 mo[6,10]	3-4[6,10]	85-94[12]
Moustache	2-5 mo[6]	1.5[6]	34
Beard	1 y[14]	2.5[8,14]	
Chest		2.5[6]	
Axillae			31-79[11,12]
Arms	1-3 mo[3,6]	2-4[3,6]	72-86[3,12]
Thigh	1-2 mo[3]	2-3[3]	64-83[3,11]
Legs	4-6 mo[6]	3-6[6]	62-88[12]
Pubic hair			65-81[11,12]

*The means to determine duration of telogen and anagen were not standardized and vary greatly between authors.

papilla.[20] Oliver evaluated the removal of different lengths of follicle so that less than or equal to half of the upper region of the follicle was left in situ. After the cut whisker shafts were plucked from these follicle remnants, the mouths of the follicular tubes left by the plucked whisker was left open or isolated dermal papillae were placed here. Fourteen of 19 of the follicular segments with papilla implants produced whiskers versus none of the follicular segments without papilla implants; this confirmed that nonregeneration of papillae and whiskers from the upper two thirds of the follicle arose from the inability of the mesenchymal layer to form papillae at this level and not from the incompetence of the outer root sheath to become organized for hair production. "Although it seems most likely that it is the dermal element of the follicle which initiates whisker growth…the signal for the mesenchymal layer to form a dermal papilla may still ultimately come from the outer root sheath and in the upper two-thirds of the follicle it is unable to give this signal."[20] (p 49) Another study from Oliver[21] examined hair regeneration from the standpoint of preservation of the papilla versus the follicle and found that isolated vibrissae papillae could induce follicle formation from ear epidermis as well as a follicular scrotal sac epidermis and from oral epithelium.

Clearly, although the dermal papilla is critical to growth, it can be replaced by mesodermal tissue under follicular epithelial cell influence. Where and what these multipotent epithelium-derived cells may be has recently been a subject of great discussion. Costarelis, Sun, and Lavker[16] have determined that in mice, a group of specialized slow-cycling cells of the outer root sheath residing in the bulge region in a fixed protected position have properties consistent with the follicular stem cells, but whether these data can be completely reconciled with Oliver's experiments is unclear.[22] Reynolds, Jahoda and Lawrence[23,24] have identified a population of germinative epidermal cells in the lower end bulb region of anagen hair follicles in both rats and humans that are distinct from epidermal or outer root sheath cells and remain quiescent in culture unless cultured in association with hair follicle dermal papilla cells, in which case they become proliferative, aggregative, and form organotypic structures. "At telogen it is not clear whether the germinative cells remain as a permanent population or are replaced, or augmented by outer root sheath cells"[25] (p 227) perhaps from the bulge region.

Kim and Choi[26] have recently reported on transection experiments, similar to those of Oliver, on human occipital scalp hairs with reimplantation of transected hairs into nonscalp (forehead or leg) skin. Sectioning was done (1) just below the sebaceous gland (upper one third of the follicle), (2) through the isthmus in the middle of the follicle, or (3) below the level of insertion of the arrector pili muscle/bulge region (lower one third of the follicle). Follicular transplants from the lower two thirds, lower half, and upper two thirds of the follicle developed into normal sized hairs. Transplants from the upper one third and lower one third of the follicle did not regenerate hair. Follicular transplants from the upper half of the follicle produced fine hairs. The conclusion was that the mid-follicle or isthmus portion of the follicle is necessary for regeneration of the hair follicle.

In terms of permanent hair removal, these data are extremely important because it shifts the potential target of destruction from only the hair bulb/dermal papillae area to other areas of the hair follicle as well.

METHODS OF HAIR REMOVAL

Shaving/Abrasives

In neonatal mice, shaving may trigger a switch from synchronous telogen to anagen.[27] This may have led to false assumptions that in humans shaving induces hair growth but shaving does not affect the rate or duration of the anagen phase or diameter of human hair.[28] Shaving does cause substitution (when the growing hair again projects beyond the skin surface) of a blunt tip versus the naturally tapered tip of uncut hair, which may give the illusion of thicker hair. Shaving of facial hair is generally shunned by women because of this and because of a masculine quality attributed to the act of shaving. However, it is a reasonable technique to use and one whose major side effects are irritation, pseudofolliculitis (with very curly hair and a very close shave), and the necessity of frequent treatment because it does not interrupt the anagen cycle.

Abrasives work to remove hair by physically rubbing the hair away from the skin surface; they are rarely used today. They consist of various stonelike materials and abrasive sandpaper and carborundum preparations.[29,30]

Epilation

In mice and rats, plucking of the hair, analogous to wounding, causes epidermal hyperplasia and initiates follicular activity in telogen hairs.[31,32] Epilation does not usually change the rate or duration of growth (or hence the eventual length of hair) unless the hair plucked is in anagen, in which case the duration of anagen may be contracted.[9,31,32] Repetitive plucking, however, may lead to permanent matrix damage[33] and finer, thinner hairs. In humans, plucking may lead to a delay in reappearance of an anagen hair that may or may not be indicative of a normal sojourn in telogen and will vary depending on a given body area: 129 days for the crown of the scalp, 123 days for the axilla, 121 days for the thigh, 92 days for the chin, and 64 days for the eyebrow.[8]

The so-called electronic tweezers (eg, Depilatron, Permatron, Removation) are little more than sophisticated (and slower) means of plucking that may, in addition, be dangerous to patients with cardiac pacemakers thus treated.[34] The radiofrequency tweezers (Nutrolysis) have also not been proven to provide anything other than temporary (and time-consuming) hair removal. The Epilady device merely plucks multiple hairs at once, as does waxing. "Threading" involves using a twisted loop of thread pulled across the skin that catches hairs and either pulls them out or breaks them off.[30] Waxing involves application of hot molten wax (although some can be applied cold) admixed with resins with or without mineral oils and perfumes to the hair-bearing skin and then stripping off the cooled stiff wax along with embedded hairs by quick stripping motions in the direction against which the hair lies on the skin.

Side effects of plucking, especially more than one hair at a time, may include postinflammatory hyperpigmentation, folliculitis, pseudofolliculitis, and even scarring.[30,35] Side effects of waxing include the aforementioned as well as greater discomfort and expense. All epilating techniques require the hair to grow long enough for the hair to be grasped by the device involved (for waxing, approximately 2 to 3 mm).

Depilatories

Chemical depilatories are simple and painless to use, readily available, and can give results that last up to 2 weeks. The most widely used varieties are substituted mercaptans, 2% to 10% thioglycolates, mixed with 2% to 6% of either NaOH or CaOH.[7,36,37] The thioglycolates disrupt disulfide bonds, especially those involving cystine. Cystine is found in greater quantities in hair versus skin keratin, thus primarily targeting the structural integrity of hair over epidermis.[37] The alkali is added to increase the pH, and hence the efficacy, of the thioglycolate. The depilatory is spread on the area of unwanted hair for 3 to 15 minutes with the resultant disolution of the hair shaft into a jellylike mass. The depilatory and the dissolved hair are then wiped off and the area washed off with soap and water.

The calcium salt of the thioglycolate is the least irritating salt form and a concentration of more than 4% is no more effective and may be more irritating. Powder formulations are more difficult to use and potentially more irritating than pastes, creams, or lotions. The depilatory should first be applied to a test site, usually the arm, and evaluation done at 24 to 48 hours; this is to ensure the integrity of the underlying skin. The primary potential side effect of depilatories is an irritant dermatitis (1% to 5%), which can be controlled with decreased frequency of application, lower concentration or pH, or a different vehicle (label shopping must be done). One percent hydrocortisone or an (acidic) emollient applied after use may also decrease any potential irritation. Allergic contact dermatitis is rare and may be related to either concomitant fragrance or to the thioglycolate.

Strontium, calcium, or barium sulfide depilatories (all powders) are inherently faster and more effective hair removers but are also more irritating than thioglycolates. The sulfide depilatories produce an objectionable odor of hydrogen sulfide gas and are poisonous if ingested.[7]

Radiation

Both a temporary and a permanent epilation have been reported after irradiation. The doses required to cause epilation vary between individuals and in different areas of the body. Scalp hair is the most radiosensitive with a progressive decrease in sensitivity seen with axillary hair, beard, pubic hair, and eyelashes.[38,39] This may be correlated with the progressive decrease in the percent of anagen hairs in the aforementioned body areas where the hair matrix cells serve as G_1 cells. Telogen hairs are much more radioresistant than anagen hairs.

Table II. Lasers used for hair removal

	Energy (nm)	Pulse duration	Repetition rate (Hz)	Spot size (mm)	Fluence (J/cm^2)	Target
Ruby laser						Melanin
EpiLaser	694	3 ms	0.5	7, 10	10-40	
EpiTouch Silk Laser	694	1.2 ms	1.2	5, 6	5-40	
Chromos	694	0.5-1.2 ms	1.2	7, 10	3-20	
Diode						Melanin
LightSheer	800	5-30 ms	1	9×9	10-40	
Alexandrite						
PhotoGenica LPIR	755	5, 10, 20 ms	1	7, 10	1-40	Melanin
Apogee	755	5, 10, 20 ms	1	7, 10, 12.5	1-50	Melanin
EpiTouch 5100, scanning	755	2 ms	5	5, 10	10-25	Melanin
GentleLase	755	3 ms	1	8, 10, 12	10-100	Melanin
Neodymium:YAG						
SoftLight	1064	10 ns	10	7	2.5-3	Topically applied carbon chromophore
*EpiLight**	Pulsed light source with filters at 590, 615, 645, 690	Variable	Variable	10×45, 8×35	30-65	Melanin

*The EpiLight is not a true laser (ie, monochromatic light source).

The dose of radiation necessary to cause temporary alopecia is dependent on the quantum energy of the type of radiation and the size of the field of radiation. For example, 100 keV unfiltered x-ray of 300 to 400 cGy each for 5 treatments, a prior treatment for tinea capitis, generally saw hair regrowth by 8 to 12 weeks. After electron beam therapy with 4 meV $\times$ 3000 to 3600 cGy in divided treatments of 4 (two of overlapping fields) per week for 8 to 10 weeks, hair regrowth usually takes 3 to 6 months, but permanent epilation may occur depending on the daily irradiation dose and the interval between doses. Permanent epilation can be seen with deep x-ray (180-200 keV, 0.5-1 mm copper filter) at a dose of more than 300 cGy or with soft x-rays (50 keV; 1 mm aluminum filter) at 5000 to 6000 cGy.[39]

Lasers

Several different lasers have been introduced for hair removal. The lasers vary in the active medium and, hence, in the wavelength of the monochromatic light produced (Table II).[40-54] The absorption of the laser light by a specific chromophore, regardless of the active medium, transforms the energy into heat with the rate and extent of heating determined by the power density (power output/effective spot size) and the duration of exposure. The resulting thermal damage can lead to denaturization or irreversible coagulation of proteins or, if the temperature is more than 100°C, vaporization of tissue.[53]

The principle of selective photothemolysis predicts that thermal injury will be restricted to a given target if there is sufficient selective absorption of light, and the pulse duration is shorter than the cooling time or thermal relaxation time (TRT) of the target.[43] The selective targets identified thus far for hair are either melanin or an exogenous substance topically applied and absorbed down the follicle. Melanin, which absorbs broadly across the optical spectrum,[54] is found in the bulb of the anagen hair, the hair shaft, and parts of the outer root sheath. The limiting factors in selecting melanin as the target for laser hair removal are that melanin is also found in the epidermis and that hair pigmentation varies widely. This has two potential consequences; there may be inadvertent damage to the epidermis with treatment and/or there may be absorptive interference by epidermal melanin.[41] The ideal laser pulse duration should thus be between the TRT for the epidermis (3-10 msec) and the TRT for the hair follicle (40-100 msec for terminal hair follicles measuring 200-300

μm in diameter).[41,42] The ruby laser (694 nm), the alexandrite laser (755 nm), and semiconductor diode laser (800 nm) target melanin.

The 3 ruby lasers currently in use for hair removal differ in the power, pulse duration, fluence, and/or spot size (Table II). They all use the active medium of a ruby (aluminum oxide) crystal doped with chromium ions, which emits energy at 694 nm in the red portion of the visible spectrum.[53] Doping is a process by which the crystal is grown in the presence of an impurity so that the crystal lattice forms with the impurity bound within it. The ruby laser may be Q-switched (very short single pulses of extremely high power) or pulsed and is absorbed strongly by eumelanin and only slightly by hemoglobin. The Epilaser (Palomar), a normal-mode ruby laser, has a 3-msec pulse, a fluence of 10 to 40 J/cm^2, and a pulse frequency of 0.5 Hz with a 7- to 10-mm beam diameter.[41] It uses a cold (4°C) sapphire lens in contact with the skin to provide a convergent beam and to limit heat conduction. An early published study of 13 patients on the thighs or back showed that one treatment caused a delay in hair regrowth of 3 months but that by 6 months after treatment, most of these patients showed significant regrowth (9 of 13 with ≥50% regrowth but 2 of 13 with < 50% regrowth; 2 of 13, no regrowth).[42] Seven of these 13 patients were followed up for 2 years; 4 of 7 showed sustained diminution in hair growth at 1 and 2 years.[43] No significant fluence-response relationship was noted between 30 and 60 J/cm^2 for temporary hair removal, but long-term hair loss was fluence related.[43] In another trial of 100 subjects using fluences greater than 30 J/cm^2, 72% of subjects had measurable hair loss that was stable at 6, 9, and 12 months after treatment (written personal communication, C. Dierickx, summer 1998). Immediate effects (after first determining fluence threshold for epidermal damage and treating below this fluence) included edema and erythema, which generally resolved within 1 to 24 hours. Early histologic effects 2 hours after treatment included heterogeneous but widespread injury to the follicular epithelium as shown by cytoplasmic eosinophilia and nuclei condensation/elongation, basophilic staining of collagen, and asymmetric focal ruptures of the follicular epithelium. Clinical hyperpigmentation and hypopigmentation from treatment were inversely related to skin type but generally cleared within months after treatment. No scarring was noted.

Other commercially available ruby lasers include the EpiTouch (Sharplan),[44] a dual-mode ruby laser used in the normal pulsed mode for hair removal. The pulse duration is 1.2 msec, frequency 1.2 Hz with a 4- to 6-mm beam. The EpiTouch uses a 0°C transparent cooling gel applied before laser treatment to reduce epidermal damage and pain. Studies with the EpiTouch have shown the need for multiple treatments for longer effects and the differential effect on hair growth depending on body site. Lask et al[40] reported 40% to 80% regrowth at 12 weeks using the EpiTouch at 18 to 25 J/cm^2 on arm hair.[35] Using 25 J/cm^2, Nestor[44] reported regrowth in the arms, legs, and/or bikini area after one or two treatments as 60% and 25%, respectively, at 3 months and less than 10% at 12 months after a third treatment. In comparison, treatment of the moustache and beard area with 25 J/cm^2 showed regrowth of 55%, 40%, and 25% after 1, 2, or 3 treatments, respectively, 1 month later. After 4 or 5 treatments over 7 months with the Epitouch, there was less than 10% regrowth at 12 months.[38] Unfortunately, there was no follow-up reported more than 6 months after treatment with the EpiTouch. Chromos 694 (Mehl Biophile) is a normal mode ruby laser with 0.5-msec pulse duration, a fluence of 10 to 15 J/cm^2, and a 5-mm beam diameter.[44] Little specific data regarding efficacy are currently available for this laser.

The Light Sheer diode laser has a wavelength of 800 nm (near-infrared spectrum), pulse duration of 5 to 30 msec, fluence of 10 to 40 J/cm^2, a 9-mm^2 spot size, a pulse frequency of 1 Hz, and a cold sapphire tip (Optiwand). Fifty-eight patients with skin types I through V with various hair colors were included in a study in which 8 test sites on each patient were shaved and treated with fluences between 15 and 40 J/cm^2 (written communication, Christine C. Dierickx, summer 1998). One year after one treatment, there was a 32% decrease in hair growth in the test sites treated with the highest fluence of 40 J/cm^2 compared with a 45% decrease after two treatments 1 month apart and a 5.3% decrease in the control shaved area. Histologic examination showed miniaturization and granulomatous degeneration of the hair follicles. The patients with blond hair did not respond as well as those with dark hair. The degree of long-term hair reduction was fluence-dependent. The most common side effect was transient hypopigmentation or hyperpigmentation in 10% of cases,

which cleared in 1 to 6 months. Moderate pain, perifollicular erythema, and edema occurred commonly and resolved within 24 to 48 hours after each treatment. The overall incidence of side effects was lower with the diode than with the ruby laser owing to the longer wavelength and longer pulse duration.

The long-pulsed alexandrite laser (LPIR [Cynosure], EpiTouch 5100 [Sharplan], and Gentlelase [Candela]) produces laser light of 755 nm.[46] According to promotional materials, 3 to 4 treatments with the LPIR at 4- to 6-week intervals at up to 40 J/cm^2 led to 80% to 100% hair reduction, but long-term efficacy results are lacking. The results with the EpiTouch 5100 after 3 treatments with 20 to 40 J/cm^2 1 to 2½ months apart on the sideburns, bikini line, underarms, and/or back showed only 5% to 15% regrowth 3 months after the last treatment.[46] The Epitouch system uses a water-based, room-temperature gel applied before irradiation to serve as a heat sink to cool the epidermis. The LPIR has a cooling tip handpiece and the Gentlelase uses a cryogen spray (Dynamic Cooling Device) as a cooling method. The 755 nm wavelength may theoretically be less absorbed by epidermal melanin than the ruby laser at 694 nm, but side effects of both lasers currently appear similar.[45,46]

The active medium of a neodymium:YAG laser is a yytrium-aluminum-garnet crystal doped with 1% to 3% neodymium ions to produce laser light in the near-infrared spectrum at 1064 nm.[53] It may be continuous wave, pulsed, or Q-switched. At the 1064 nm wavelength, melanin, hemoglobin, and water absorb this light poorly.[53] Precisely because of this potential safety measure, one commercial manufacturer (SoftLight, Thermolase Corporation) has used the neodymium:YAG laser in conjunction with a topical preparation of a carbon-based material in mineral oil.[41,45,47,48] Before treatment, the area to be treated is epilated (waxed) or shaved and the topical preparation massaged into the skin and, by extension, into the follicular tracts. A pulse duration of 10 nsec, frequency of 10 Hz, fluence of 2 to 3 J/cm^2, and a 7-mm spot size are used. When the carbon particles absorb infrared light, focal photomechanical damage is caused by the short nanosecond pulse.[36] Edema and erythema may be present for 24 to 48 hours after treatment and petechiae for up to 5 days. All skin types can be treated, as opposed to lasers that target melanin, but reported efficacy is only a temporary growth reduction in 50% of patients at 3 months with full regrowth by 6 months.[45] Preliminary studies indicate that neither the carbon-containing solution nor the wax epilation significantly affects the 3-month results.[49]

The intense pulsed light system of ESC Medical Systems, the EpiLight, is not a laser because the light generated is not monochromatic.[50] The 550- to 1200-nm light pulses are created by a flashlamp, focused by a reflector, and transmitted through a set of filters that determine its spectral characteristics. For hair removal, the filters tailor the spectrum of light to the skin type and hair color of the patient. A study of 37 test sites in 31 patients using filters of 590 to 690 nm, pulse sequences of 2 to 5 pulses of 1.5 to 3.5 msec separated by delays of 20 to 50 msec, a fluence of 34 to 55 J/cm^2, and a spot size of either 10 × 45 mm or 8 × 35 mm, and a cooling gel applied topically showed that at 2 months approximately 25% of sites had less than 25% regrowth, approximately 35% had 25% to 50% regrowth, and approximately 40% of sites had 50% or more regrowth.[50] Ninety patients with skin types I through V with 185 sites treated biweekly × 4 treatments with wavelength of 590 to 695 nm, fluence of 33 to 60 J/cm^2, over 2 to 5 pulses lasting 2.5 to 3.5 msec had regrowth of 48% at 6-month follow-up.[51] A smaller study of 9 patients with similar treatment parameters showed a decrease of 20% to 75% (mean, 47%) in treated hairs at 6-month follow-up.[52] As with laser hair removal devices, multiple treatments will improve efficacy. It has been hypothesized that patients with darker skin color may be able to use this method without pigmentary problems, although both hyperpigmentation and blistering have been seen after treatment.[50] Transient erythema is common after treatment.

All of the presently utilized lasers have been approved by the Food and Drug Administration devices section, which requires only that the lasers (or any hair removal device) prove a sustained diminution in hair growth over a 3-month period. None of the presently utilized lasers has been proven to permanently destroy hair. Recently, Palomar was the first company given approval by the Food and Drug Administration to market a laser (the Epilaser) for "permanent hair reduction," defined as a lasting reduction in treated hairs for a period greater than the complete hair cycle of hairs in the treated area. At this point, the reported dura-

tion of the hair cycle in various body regions is only an estimate needing further clarification. In addition, because injury can cause a prolonged delay of hair regrowth (it may take 6 months or more after electron beam irradiation for hair to regrow), any treatment purporting permanent hair destruction should include a period for recovery from injury (≥ 6 months) in addition to that of one complete (anagen to anagen) cycle (Table I). Injury also triggers a telogen to anagen switch so that the laser treatment may initially synchronize the hair cycle in a treated area; this may have a salutary effect because it is clear that telogen hairs are radioresistant and injury-resistant and that any hopes for permanent hair removal must target the anagen hair. Permanency in regard to hair removal should be proved by histologic destruction of the follicles in a previously treated area.

A word should also be said about the commercial practices of some companies producing lasers for hair removal. As of March 1998, some laser companies do not allow a physician to purchase their laser outright or may require a physician leasing the device to pay a set amount per treatment as well as a minimum amount per month to the leasing company regardless of the number of patients treated. Contracts that specify a given dollar amount per treatment or a percentage of the amount billed to the patient for the treatment result in fixing prices for the patient, often at an inflated level. Some contracts even have a "gag" clause that prohibits physicians from publicizing negative results or tie refunds to nonpublication of the reason for returning the device to the manufacturer. The lack of comparative data make it difficult for both physicians and patients to choose the most effective laser treatment for hair removal. Moreover, patients' expectations will be dashed, physician reputations diminished, and litigation initiated if it is not made clear to patients before the onset of laser treatment the limitations of data regarding duration of hair removal in treated areas for that particular laser.

PHOTODYNAMIC THERAPY

Photodynamic therapy involves the combination of nonionizing radiation with a topical or systemic photosensitizer.[53] Light of an appropriate wavelength is selectively absorbed by the photosensitizing compound and may then activate the chemical reactions directly or transfer energy to molecular oxygen, producing a reactive intermediate, singlet oxygen.[54] The most significant effects of singlet oxygen are lethal alterations of cellular membrane systems through lipid peroxidation and protein damage. As oxygen is consumed during the reaction at rates which can produce tissue hypoxia, this can both be a mechanism of tissue damage and a self-limiting effect since oxgen is required to produce the singlet oxygen. Most recently, topical aminolevulenic acid (ALA) has been used in a trial for hair removal.[55] ALA is not itself a photosensitizer but induces the synthesis of one, protoporphyrin IX. In a preliminary report on its use, the area to be treated was either first wax epilated or shaved and then a 20% ALA-containing lotion applied. The area was then exposed to an argon pumped dye laser at 630 nm with fluences of 100 to 200 J/cm^2. At 3 months, there was 50% regrowth in the sites exposed to 200 J/cm^2 versus 90% or more regrowth in the sites exposed to 100 J/cm^2, similar to control sites.[55]

ELECTROLYSIS

Electrolysis is a reasonable means of removing hair and, short of surgical excision of the hair follicle or certain doses or timing of x-ray therapy, the only other proven permanent means of hair removal. However, electrolysis is much maligned by physicians as a means of hair removal, probably for several reasons. First, there is absolutely no standardization of licensure to practice electrolysis; some states have either no requirements (n = 18) or require as little as a ninth-grade education.[56] Those states that do have licensing boards often require rigid and lengthy training at a few sanctioned schools and often do not recognize training of personnel in physicians' offices. Second, grouped under the umbrella term "electrolysis" are techniques that only have in common an electric current delivered by a probe placed in contact with a hair. Neither the public nor medical personnel have been educated in the multitude of differences in electrolysis, including the type of electrolysis used, the particular machine, probe, pulse duration, and timing of treatment. Grouping all electrolysis together is analogous to grouping all lasers together as "one" form of treatment without recognizing the inherent differences in the laser medium, tissue effects, and safety issues as well as the importance of fluence and pulse duration. Third, there are no controlled trials and little

scientific data on electrolysis on which to base efficacy. Fourth, there is the misconception that electrolysis is necessarily unduly painful, causes scarring, or takes an unreasonably long course of treatment to accomplish permanent hair removal.

There are two main types of electrolysis, galvanic (or direct current electrolysis) and thermolysis (or alternating current electrolysis).[7,56-58] Galvanic electrolysis, which is the older of the two modalities and the one that most electrologists working in their own offices use, is based on the principle of chemical destruction of the hair follicle. With direct current, the chemical reaction of $2NaCl + 2H_2O \rightarrow 2NaOH + H_2 + Cl_2$ occurs in the tissue wherever the metal of the probe is in contact with the follicle or skin and while the current is flowing. The hydrogen gas so produced escapes from the follicle, often with bubbles, and the chloride is deposited at the cathode as very dilute hydrochloric acid. A metal rod covered with conductive cream or gel or a metal plate attached to a pad moistened with water or saline is attached to or held by the patient during the procedure. These conducting rods or plates serve as the cathode and good contact is necessary for the current to complete the circuit in the machine and not on the patient's skin surface. The current (in milliamperes) of galvanic electrolysis is set by the operator with the maximum current based on the individual patient's perception of pain. Depending on the machine, there may be fluctuation of the current with galvanic electrolysis (even without changing the setting), and the determination of intensity is inexact. The duration of the treatment of each individual hair is determined by how long the operator depresses the hand or foot pedal. Galvanic electrolysis is slow and each hair may take 15 seconds to 3 minutes to remove and repeated insertions are often neccessary. To speed up the process of galvanic electrolysis, more than one probe may be inserted simultaneously. A tweezer "galvanic electrolysis device" has been developed using the tweezer as the electrode but other than demonstrating an increased pH of the treated and epilated hair (information provided by Guaranty Hair Removal), there are no published data to prove any damage to the follicular apparatus as with standard galvanic electrolysis or any effect other than temporary hair shaft removal.

Thermolysis involves alternating, not direct, current and causes destruction of the hair follicle by thermal, not chemical, means. It is basically high-frequency (27.125 MHz established by the Federal Communications Commission) electrocoagulation, with the needle or probe acting as the electrode. Thermolysis can be uniterminal, which eliminates the need for grounding electrodes, or biterminal, which requires grounding but eliminates the capitance function of the body.[57] Unipolar diathermy does not generate any heat in the needle or skin surface but only in the tissue itself secondary to the resistance of the current; it is less painful and generally faster than bipolar diathermy.[59] The uniterminal thermolysis may be either of low intensity over 3 to 20 seconds or high intensity ("flash") over 0.02 to 0.5 seconds. The short current duration, which is set by the machine and not the operator in the case of thermolysis, is able to minimize or even remove any discomfort the patient may feel from the higher intensity. As in galvanic electrolysis, the higher intensity is more effective for hair removal. A combination of thermolysis and galvanic electrolysis can be used together ("The Blend") but would appear unnecessary with an effective thermolysis machine and competent technician. Neither form of electrolysis is safe for patients with pacemakers to use.

The needles or probes used in electrolysis vary greatly. Reusable needles are generally favored by electrologists in the field but as the standards for sterilization and policing of same vary greatly from state to state, individual-use needles or probes offer greater safety for patients. The diameter of the needle inversely correlates with the intensity of the heating as a smaller needle disperses the same energy over a smaller surface area. Needles are pointed and rigid, whereas probes can be bulbous tipped and flexible or rigid; the chance for piercing the follicular wall increases with the sharpness of the tip, the rigidity of the electrode, and the inherent curvature of the follicle. Insulated needles are available with the upper part of the needle purposefully insulated to protect the infundibular portion of the follicle. Yamada[60] has reported that terminal hairs are 1 to 4.5 mm in length and vellus hairs 0.5 to 1.5 mm in length from the skin surface. A histologic study of an insulated, flexible, bulbous-tipped probe in conjunction with an LPS 1118 (Integrated System) thermolysis machine at 50% to 60% power and pulse duration of 45 to 50 msec compared with a bare rigid needle in conjunction with a Kree ther-

molysis machine at 85% to 100% full power with a 0.3- to 1-second pulse duration was performed on scalp and leg hair.[50] Four to 7 weeks after conventional (galvanic) electrolysis, there was a moderate-sized zone of hyalinized collagen around the upper follicles consisting of thin parallel collagen bundles with fibrotic streamers replacing the entire lower follicle and degenerating papillae below this.[61] In comparison, 4 to 7 weeks after treatment with the Integrated System and insulated probe, the perifollicular zone of hyalinized collagen was much narrower than that seen with conventional electrolysis and the larger sebaceous lobules had regenerated and were attached to well-formed infundibulum. Fibrous streamers also replaced the lower two thirds of the follicle with this technique, and papillae were no longer obviously present. Kobayashi[60] also reported on insulated needles. He found that insulation at the top 1 mm of a 4-mm probe protected the epidermis from damage and preserved the infundibulum but led to destruction of the isthmus and lower follicle. Using a greater degree of insulation (2 mm total) led to preservation of the upper segment of deep terminal follicles and the entire follicle of those located more superficially. Given what we now know of the potential factors in control of hair growth, these data regarding probe insulation may be particularly important. As McKinstry, Inaba, and Anthony[62] showed, only when the follicular isthmus was destroyed by electrolysis was the hair removal permanent. This information obviously has implications well beyond electrolysis.

Most electrologists in practice treat all hairs, both telogen and anagen, in a given area. However, as noted earlier, telogen hairs are notoriously more resistant to damage than anagen hairs and thus may be expected to regrow after treatment with either galvanic electrolysis or thermolysis. An effective treatment plan for electrolysis should include treatment of only anagen hairs and use of the knowledge (even as poorly defined as it is) of the specifics of the hair cycle for the region being treated. With this in mind, one can get a sense of the comparative differences among the various hair removal techniques in the total time necessary to remove hair in a given area. Anagen hairs can be discriminated from telogen hairs by shaving the area to be treated and having the patient return in a few days; at that time, the only visible hairs will be anagen hairs. Richards, McKenzie, and Meharg,[63] using thermolysis and/or the Blend and either the Dipilamax or Fischer brand machines, primarily slow current (2-7 seconds), and an uninsulated needle and asking but not requiring patients to shave 1 to 3 days before treatment (to isolate only anagen hairs for treatment) reported that women with heavy facial hair would require 2 to 3 hours per week of electrolysis for 2 years followed by 30 minutes every other week for an undetermined length of time, a total of at least 210 hours. This would be required to make the area not necessarily free of hair but with marked diminution of terminal hair in the treated area (assuming no underlying androgen excess problem driving the process). Using the Integrated System (thermolysis) reported by Peters and Kligman and as outlined earlier (which targets only anagen hairs), treatment of a similar woman with hirsutism would be staged on the basis of the hair cycle of the beard and moustache area with half of the terminal hair permanently removed in the first 3 to 4 months of treatment and the remainder of the hair in the area removed over the rest of the 18-month treatment period (unpublished information, Lucy Peters). No direct comparative results as far as time, cost, or efficacy with thermolysis versus galvanic electrolysis or between different types of thermolysis have been reported. It should be clearly stated to patients with hirsutism that if the cause of their hirsutism is not identified and any androgen excess not addressed medically (or surgically), despite the effective permanent destruction of the hairs treated with electrolysis or laser, they will continue to see the conversion of vellus hairs to terminal hairs in the treatment areas and that this must not be misconstrued as treatment failure for the technique. Even if they have only idiopathic hirsutism (androgen hypersensitivity with normal androgen levels), they may still have some vellus to terminal hair conversion in androgen-dependent treated areas.

Side effects of electrolysis include pain, scarring (and keloid formation in susceptible patients), and postinflammatory hypopigmentation or hyperpigmentation, all of which are dependent on the type of electrolysis and the duration and intensity of the current. They are thus related to both the machine and the operator. Topical anesthetics such as lidocaine or eutectic mixture of local anesthetics (EMLA) may be used before treatment, but it is often useful to maintain sensation during electrol-

ysis treatment because skin damage and pain are interrelated. Local infection and the inherent risk of endocarditis in a susceptible patient are related to the operator's cleaning of instruments and pretreatment of the patient's skin. Gloves should be worn by all operators and an antibacterial ointment applied afterward. Recurrent herpesvirus infection may be initiated as with any trauma and either herpes, molluscum contagiosum, or human papillomavirus can be spread from treated areas; as with lasers, patients with recurrent herpes infection after treatment should consider taking antiviral prophylaxis. The spread of hepatitis and AIDS has not been reported with electrolysis. Erythema and edema are common problems after treatment but generally dissipate over the hour directly after treatment. Crusting or follicular nodules are generally related to repeated insertions in the same follicle and can persist for several days or longer. Scarring can be prevented by ensuring that the needle does not perforate the follicular duct during treatment and by using short pulses to minimize perifollicular damage.

SUMMARY

This article has attempted to review all the current methods, both temporary and permanent, of hair removal that can be used with both androgen-dependent and androgen-independent unwanted hair. Some standardization of efficacy parameters regarding permanent hair removal and comparative trials of different hair removal methods are sorely needed to put relative efficacy of all these techniques in perspective. I suggest that at a minimum the following be performed:

1. In women, non-androgen-dependent areas of hair growth should be chosen for study. In both sexes, study areas should have equivalent hair density at baseline.
2. Potential primary end points for efficacy may include number of total hairs, number of terminal hairs, mean hair width, and/or hair weight in the treated area at baseline, end of treatment and, importantly, for a designated time period (different for different body areas) after treatment. This posttreatment period ideally should include the time of 1 complete hair cycle for that body area plus an additional 6-month "recovery" time. Any hair loss treatment deemed to be permanent should be assessed as such only after this period after treatment has elapsed.
3. Patient assessment of hair growth both before and after treatment should also be considered.

REFERENCES

1. Abell E. Embryology and anatomy of the hair follicle. In: Olsen EA, editor. Disorders of hair growth: diagnosis and treatment. New York: McGraw-Hill; 1994. p. 1-19.
2. Courtois M, Loussouarn G, Hourseau C, Grollier JF. Ageing and hair cycles. Br J Dermatol 1995;132:86-93.
3. Seago SV, Ebling FJG. The hair cycle on the human thigh and upper arm. Br J Dermatol 1985;113:9-16.
4. Randall VA, Ebling FJG. Seasonal changes in human hair growth. Br J Dermatol 1991;24:146-51.
5. Eaton P, Eaton MW. Temperature and the growth of hair. Science 1937;86:354.
6. Saitoh M, Uzuka M, Sakamoto M. Human hair cycle. J Invest Dermatol 1970;54:65-81.
7. Olsen EA. Hypertrichosis. In: Olsen EA, editor. Disorders of hair growth: diagnosis and treatment. New York: McGraw-Hill; 1994. p. 315-36.
8. Myers RJ, Hamilton JB. Regeneration and rate of growth of hairs in man. Ann N Y Acad Sci 1951;53:562-8.
9. Hale PA, Ebling FJG. The effects of epilation and hormones on the activity of hair follicles. J Exp Zool 1975; 191:49-62.
10. Pinkus F. Die normale Anatomie der Haut. In: Jadassohn J, editor. Handbuch der Haut- und Geschlectskrankheiten I. Band I. Berlin: Springer-Verlag; 1927. p. 1-378.
11. Trotter M. The life cycles of hair in selected regions of the body. Am J Phys Anthrop 1924;7:427-37.
12. Braun-Falco O, Heilgemeir GP. The trichogram, structural and functional basis, performance and interpretation. Semin Dermatol 1985;4:40-52.
13. VanScott EJ, Reinertson RP, Steinmuller R. The growing hair roots of the human scalp and morphologic changes therein following amethopterin therapy. J Invest Dermatol 1957;29:197-204.
14. Braun-Falco O. Dynamik des normalen und pathologischen Haarwachstums. Arch Klin Exp Dermatol 1966; 227:419-52.
15. Headington JT. Telogen effluvium. Arch Dermatol 1993;129:356-63.
16. Cotsarelis G, Sun T-T, 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;61:1329-37.
17. Oliver RF. Whisker growth after removal of the dermal papilla and lengths of follicle in the hooded rat. J Embryol Exp Morphol 1966;15:331-47.
18. Oliver RF. Histological studies of whisker regeneration in the hooded rat. J Embryol Exp Morphol 1966;16: 231-44.
19. Oliver RF. Ectopic regeneration of whiskers in the hooded rat from implanted lengths of vibrissa follicle wall. J Embryol Exp Morphol 1967;17:27-34.
20. Oliver RF. The experimental induction of whisker growth in the hooded rat by implantation of dermal papillae. J Embryol Exp Morphol 1967;18:43-51.
21. Oliver RF. The induction of hair follicle formation in the adult hooded rat by vibrissa dermal papillae. J Embryol Exp Morphol 1970;23:219-36.
22. Holecek B-U, Ackerman AB. Bulge-activation hypothesis: Is it valid? Am J Dermatol 1993;15:235-47.
23. Reynolds AJ, Jahoda CAB. Hair follicle stem cells? A distinct germinative epidermal cell population is activat-

ed *in vitro* by the presence of hair dermal papilla cells. J Cell Sci 1991;99:373-85.
24. Reynolds AJ, Lawrence CM, Jahoda CAB. Human hair follicle germinative epidermal cell culture. J Invest Dermatol 1993;101:634-8.
25. Reynolds AJ, Jahoda CAB. Inductive properties of hair follicle cells. Ann N Y Acad Sci 1991;642:226-42.
26. Kim J-C, Choi Y-C. Hair follicle regeneration after horizontal resectioning: implications for hair transplantation. In: Stough DB, Haber RS, editors. Hair replacement: surgical and medical. St Louis: Mosby–Year Book; 1995. p. 358-63.
27. Oh H-S, Smart RC. An estrogen receptor pathway regulates the telogen-anagen hair follicle transition and influences epidermal cell proliferation. Proc Natl Acad Sci U S A 1996;93:12525-30.
28. Trotter M. The resistance of hair to certain supposed growth stimulants. Arch Derm Syph 1923;7:93-8.
29. Ridley CM. A critical evaluation of the procedures available for the treatment of hirsutism. Br J Dermatol 1969;81:146-53.
30. Richards RN, Uy M, Meharg G. Temporary hair removal in patients with hirsutism: a clinical study. Cutis 1990; 45:199-202.
31. Silver AF, Chase HB, Arsenault CT. Spontaneous and experimental hair growth of the mouse pinna. J Invest Dermatol 1966;48:444-60.
32. Johnson E, Ebling FJG. The effect of plucking hairs during different phases of the follicular cycle. J Embryol Exp Morphol 1964;12(part 3):465-74.
33. Hamilton E, Potten CS. The effect of repeated plucking on mouse skin cell kinetics. J Invest Dermatol 1974;62:560-2.
34. Willis J. Some basics on hair removal products. FDA Consumer 1979;13(7):23-5.
35. Wright RC. Traumatic folliculitis of the legs: a persistent case associated with use of a home epilating device. J Am Acad Dermatol 1992;27:771-2.
36. Feldman EG, editor. Handbook of nonprescription drugs. 9th ed. Washington (DC): American Pharmaceutical Association; 1990.
37. Natow AJ. Chemical removal of hair. Cutis 1986;38: 91-2.
38. Ellinger F. Effects of ionizing radiation on growth and replacement of hair. Ann N Y Acad Sci 1951;53:682-7.
39. Grossman KL, Kvedar JC. Anagen hair loss. In: Olsen EA, editor. Disorders of hair growth: diagnosis and treatment. New York: McGraw-Hill; 1994. p. 225-6.
40. Lask G, Elman M, Slatkine M, Waldman A, Rozenberg Z. Laser-assisted hair removal by selective photothermolysis. Dermatol Surg 1997;23:737-9.
41. Wheeland RG. Laser-assisted hair removal. Dermatol Clin 1997;15:459-77.
42. Grossman MC, Dierickx C, Farinelli W, Flotte T, Anderson RR. Damage to hair follicles by normal-mode ruby laser pulses. J Am Acad Dermatol 1996;35:889-94.
43. Dierickx CC, Grossman, MC, Farinelli WA, Anderson RR. Permanent hair removal by normal-mode ruby laser. Arch Dermatol 1998;134:837-42.
44. Nestor MS. Laser hair removal: clinical results and practical applications of selective photothermolysis. Skin Aging 1998;1:34-40.
45. Nanni CA, Alster TS. A practical review of laser-assisted hair removal using the Q-switched Nd:YAG, long-pulsed ruby, and long-pulsed alexandrite lasers. Dermatol Surg 1998;24:1-7.
46. Finkel B, Eliezri YD, Waldman A, Slatkine M. Pulsed alexandrite laser technology for noninvasive hair removal. J Clin Laser Med Surg 1997;15:225-9.
47. Goldberg DJ. Topical suspension-assisted Q-switched Nd:YAG laser hair removal. Dermatol Surg 1997;23: 741-5.
48. Goldberg DJ. Topical solution assisted laser hair removal. Lasers Surg Med 1995;7:47.
49. Nanni CA, Alster TS. Optimizing treatment parameters for hair removal using a carbon-based solution and a 1064 nm Q-switched neodynium:YAG laser energy. Arch Dermatol 1997;133:1546-9.
50. Gold MH, Bell MW, Foster TD, Street S. Long-term epilation using the EpiLight broad band, intense pulsed light hair removal system. Dermatol Surg 1997;23: 909-13.
51. Smith SR, Tse Y, Adsit SK, Goldman MP, Fitzpatrick RE. Long-term results of hair photo-epilation. Lasers Surg Med Suppl 1998;10:43.
52. Sadick NS, Shea CR, Burchette JL, et al. High intensity flashlamp photoepilation: a clinical, histologic and mechanistic study of the EpiLight Hair Removal system in human skin. Arch Dermatol In press.
53. Dover JS, Arndt KS. Illustrated cutaneous laser surgery: a practitioner's guide. Norwalk (CT): Appleton & Lange; 1990.
54. Goldman MP, Fitzpatrick RE. Cutaneous laser surgery: the art and science of selective photothermolysis. St Louis: Mosby–Year Book; 1994.
55. Grossman MC, Wimberly J, Dwyer P, et al. PDT for hirsutism. Lasers Surg Med Suppl 1995;7:44.
56. Richards RN, Meharg GE. Cosmetic and medical electrolysis and temporary hair removal. 2nd ed. Ontario: Medric Ltd; 1997.
57. Wagner RF. Medical and technical issues in office electrolysis and thermolysis. J Dermatol Surg Oncol 1993; 19:575-7.
58. Erdos-Brown M. Superfluous hair: removal with the monopolar diathermy needle. Arch Derm Syph 1942;46: 496-501.
59. Wagner RF, Tomich JM, Ghande DJ. Electrolysis and thermolysis for permanent hair removal. J Am Acad Dermatol 1985;12:441-9.
60. Kobayashi T. Electrosurgery using insulated needles: epilation. J Dermatol Surg Oncol 1985;11:993-1000.
61. Kligman AM, Peters L. Histologic changes of human hair follicles after electrolysis: a comparison of two methods. Cutis 1984;34:169-76.
62. McKinstry CT, Inaba M, Anthony JN. Epilation by electrocoagulation: factors that result in regrowth of hair. J Dermatol Surg Oncol 1979;5:407-11.
63. Richards RN, McKenzie MA, Meharg GE. Electroepilation (electrolysis) in hirsutism. J Am Acad Dermatol 1986;15:693-7.