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Physical means of treating unwanted hair

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ABSTRACT: Unwanted facial and body hair is a common problem, generating a high level of interest for treatment innovations. A wide range of modalities for the management of unwanted hair have been advocated over the years with varying degrees of clinical success. Most recently, lasers and light sources have been used to address this problem with improved clinical success rates in properly selected patients. The full range of temporary and permanent hair removal techniques will be outlined in this review of physical means of treating unwanted hair.

KEYWORDS: electrolysis, epilation, hair removal, laser

Introduction

With the advent of newer methods for hair removal, many patients with unwanted hair seek advice regarding their treatment options. The causes of hirsutism and hypertrichosis are varied, ranging from hereditable factors or endocrine disorders to exogenous drug therapy (1). Increased hair density may be localized or generalized, and affect both men and women. Several factors relating to hair removal treatment are of concern to patients, including clinical efficacy, safety, expense, convenience, associated pain, and other short- and long-term side effects.

Anatomy of the hair follicle and hair growth

The hair follicle can be divided into four distinct regions – bulb, suprabulbar zone, isthmus, and infundibulum. The matrix is the actively growing portion of the hair and comprises, together with the dermal papilla, the hair bulb. Matrix cells rapidly divide, migrate upward, and are confined to the lowermost portion of the follicle. The isthmus of the follicle is the short portion located between the point of attachment of the arrector pili muscle and the entrance of the sebaceous gland duct. The infundibulum lies above the entry of the sebaceous duct to the hair follicle orifice and merges with the epidermis.

Actively growing (anagen) hairs are characterized by the hair matrix surrounding a dermal papilla with well-developed inner and outer root sheaths. On the scalp, a typical anagen follicle continues to produce a hair shaft for approximately 2 to 3 years – giving rise to longer hair. The shorter hairs found in other body locations have correspondingly shorter anagen periods. Dying or regressing (catagen) hairs are identified by markedly thickened vitreous layers and fibrous root sheaths surrounding an epithelial column. Above this column, the presumptive club forms. The catagen stage of the hair cycle, lasting only a few weeks, ends as the catagen hair enters into a "resting" (telogen) stage. A telogen hair is distinguished by its fully keratinized club, which is surrounded by an epithelial sac. Below this lies the secondary hair germ and condensed dermal papilla (2). New anagen hair growth is initiated by cells that reside in the bulge region – the protuberance of cells that serves as a point of attachment for the arrector pili muscle (3). During the 3 months of telogen, the bulge lies near the secondary hair germ.

On the scalp, the majority of hair follicles (80–85%) are in anagen phase and the remaining follicles

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Table 1. Hair growth, follicle density, and depth by body location

Body location	% Anagen hair	Telogen stage
Beard	70	10 weeks
Upper lip	65	6 weeks
Axillae	30	3 months
Arms	20	18 weeks
Legs/Thighs	20	24 weeks

are either in the catagen (2%) or in the telogen (10–15%) phase. However, on other areas of the body, anagen hairs may account for only 20–50% of the total number of hairs present. Telogen may last for a couple of months on the face and for many months on the upper arms and legs (4) (Table 1).

Anagen hairs vary in size from the large terminal hairs found in the beard and on the scalp to fine, minute vellus hairs covering most of the glabrous skin. Vellus and terminal hairs go through all stages of the follicular life cycle, but the length of anagen is much shorter in vellus hairs. Although vellus hairs cover most of the human body, terminal hairs are of more interest to both clinician and patient and their presence in hirsute conditions is the cause of much concern (2).

Temporary methods of hair removal

Bleaching

Bleaching does not remove the hair follicle, but it serves to lighten the color of the external hair shaft so that it is less noticeable. Several types of commercial hair bleaches are available: neutral oil bleaches, color oil bleaches, cream bleaches, and powder bleaches – all of which contain hydrogen peroxide as the active ingredient. While a 6% concentration of peroxide bleaches, softens, and oxidizes the hair, the addition of 28% ammonia accelerates its bleaching action. The addition of persulfate to intensify peroxide hair bleach has resulted in generalized urticaria, asthma, syncope, and shock (5). While, bleaching is a quick, easy, and painless process that can last up to 4 weeks, disadvantages of its use include skin irritation, hair discoloration, and lack of desired efficacy (6,7). This method is best used for treatment of localized excess pigmented hair on the face or arms of fair skinned patients, because yellow bleached hair is highly visible against the skin of more darkly pigmented patients (8).

Trimming

Trimming of hair is the treatment of choice for young children with either localized or generalized hypertrichosis. It is safe and does not accelerate hair regrowth (8).

Shaving

Shaving is one of the oldest and most frequently used methods of hair depilation. Contrary to popular belief, shaving does not affect the width or rate of regrowth of individual hairs (9); however, the rough stubble following shaving may be undesirable. In general, safety razors have been preferred over electric razors by both men and women because a closer shave can be achieved. Although most women report little difficulty shaving their legs, it remains an unpopular method for the removal of unwanted facial hair. Shaving is convenient and of low cost; however, its disadvantages include skin irritation, abrasions, and stubble.

Tweezing

Tweezing or plucking is a temporary method of epilation that is used for small areas of excess hair. Drawbacks include treatment discomfort and risk of folliculitis, hyperpigmentation, erythema, follicular distortion (which makes subsequent treatment difficult), and scarring (5,6). While rare, plucking of hairs from melanocytic nevi may result in the development of foreign body granulomas around disrupted hair follicles which can develop into Nanta's osteonevus (metaplastic ossification) (10). Electronic tweezers provide inconsequential transmission of electric current into the follicle with subsequent rapid hair regrowth (11).

For more diffuse hypertrichosis, mechanized tweezers with a rotating, fine, coiled spring that grasps and pulls out the hair shaft may be used (8). The handheld device is relatively easy to operate, but can be painful.

Waxing

Waxing provides a uniform method of plucking hair. The technique involves the application of melted wax to hair-bearing skin which, upon drying, is rapidly peeled away from the skin in the direction opposite to hair growth. Caution must be used to prevent thermal burns caused by application of excessively hot wax to the skin. Also, a certain length of hair is necessary for

waxing to be successful. Waxing is inexpensive and the results are longer-lasting than with shaving or chemical depilatories because the hairs are removed from the hair bulb rather than at the skin surface. Six weeks of relatively hair-free skin is typically achieved (5). Cold semisolid waxes are also available, but are usually more expensive and cannot be reused (12). Potential allergic sensitizers in waxes are beeswax, rosin (colophony), fragrance, and benzocaine (5). In addition to treatment discomfort, waxing has been reported to cause folliculitis, skin irritation, and keloid scars (6,13). The long-term effects of waxing on the follicle are not known, but many use it repeatedly for several years without experiencing significant problems. It may even be possible to reduce the amount of hair regrowth due to repeated waxing-induced follicular trauma (6).

The non-Western technique of sugaring is another temporary hair removal method. Sugaring is similar to waxing except that a sticky paste is applied to the skin instead of melted wax or a cold polymer. Sugaring is often preferred for large surface areas, such as the back or legs (14).

Mechanical epilation

Mechanical abrasives (e.g., sandpaper, pumice stone) rubbed over a hair-bearing area in a circular motion have been used to remove hair at the skin surface, but usually also cause skin irritation and are, thus, seldom used (5,6). Threading, a method of hair removal whereby a fine cotton string is used to capture hairs, leads to removal of some hairs at their roots while others are simply cut off by the scissoring action of the twisted thread. This method is used extensively in Arabic countries and may produce folliculitis (6,15), erythema, and secondary pigmentary changes (16). Traumatic folliculitis has also been reported from home epilation devices that produce skin surface friction via circular motions over hair-bearing areas (17).

Chemical depilatory agents

Chemical depilatories act to separate the hair from its follicle and the surrounding skin surface through reduction of disulfide bonds. Because the hair shaft is composed of more disulfide-containing cysteine than is epidermal keratin, such chemicals as sulfur compounds of calcium, arsenic, antimony, barium, and strontium, can effectively dissolve the hair shaft (5,9). Newer chemical depilatory agents contain mercaptan thioglycolic acid mixed with alkali (9). With these altered formulations, the hair shaft is hydrated and disulfide bonds broken. Since chemical depilatories frequently penetrate into portions of the infundibulum, it usually takes several days before any hair regrowth is observed (5). Therefore, chemical depilatories are most appropriate for weekly hair removal from small areas.

An irritant contact dermatitis due to the alkalinity of chemical depilatories is the most frequent adverse reaction and can be avoided with the concomitant application of a topical corticosteroid. Allergic contact dermatitis may also occur due to the presence of fragrances in the preparations and cross-reactions have been observed between mercaptan and dimercaprol (5). Fewer than 1% of patients are thus able to tolerate facial application of depilatories. Additionally, many find the procedure to be excessively messy and the depilatory's smell offensive (6). Thioglycolate-containing depilatories are not recommended for men's beards because they do not penetrate the hair shafts quickly enough to be a practical alternative to shaving (9). Although strontium and barium sulfides are effective in this setting, the hydrogen sulfide gas released by these compounds yields an unpleasant odor. In addition, barium sulfide is more irritating to the skin than the more commonly used calcium thioglycolate (18).

Surgery

Surgical excision of axillary apocrine glands in patients with hirsutism and hyperhidrosis has been found to cause hair loss in the area (19). Eventual hair regrowth may be expected due to varying depths (and therefore unsuccessful destruction) of anagen, catagen, and telogen hair follicles (20). The scars that often result from surgery should be taken into consideration, as they may be cosmetically unacceptable to the patient.

Radiation therapy

In the 1920s, hypertrichosis was managed with X-ray treatment resulting in radiation-induced cutaneous malignancy, including basal cell carcinomas, trichoblastomas, and trichoblastic carcinomas on the scalp with a mean of onset of tumor development of 39.4, 38.3, and 35.6 years, respectively (21–23). Although more than 80% of the X-ray treatments were performed before 1930, the use of this therapy persisted into the 1940s (22). As safer treatment alternatives have become available over the years, radiation therapy has fallen out of favor and is not currently considered an acceptable treatment option.

Permanent methods of hair removal

Electrolysis and thermolysis

Electrolysis, thermolysis, and a combination of both are three popular procedures used for epilation or permanent hair removal and are performed more often in the USA than anywhere else in the world (5). All three methods involve the insertion of a small needle or probe into the hair follicle through which an electric current is delivered, resulting in the production of a microscar that surrounds the follicle, but is barely perceptible at the skin surface (24). Focal erythema and edema following treatment usually resolve within a few hours (25).

Electrolysis is performed by passing low flow direct or galvanic current through tissue between two electrodes which causes a chemical reaction to occur at the electrode tip, resulting in tissue damage and destruction of the hair follicle. The production of local hydroxides destroys the hair bulb and enclosed dermal papilla. While galvanic electrolysis is effective, it is a slow process, requiring a minute or more for each hair (26). Its advantage lies in its ability to effectively treat curved or distorted follicles because hydroxyl ions, being in a fluid medium, can flow to all portions of the follicle (25).

Thermolysis (diathermy) is performed using high-frequency alternating current at low voltage to thermally destroy or epilate hair follicles – a process termed electroepilation. Thermolysis has a somewhat higher risk of scarring and pain, although modern electroepilation devices have precise automatic timers and insulated probes that reduce the risks of scarring (27–29). The process is much faster than galvanic electrolysis (requiring only a few seconds per follicle); however, its destructive results are not as consistent, particularly when treating distorted or curved hair follicles (25,26). Following each treatment session of thermolysis, hair regrows in 20–40% of the follicles treated (8).

The combination method using both electrolysis and thermolysis subjects the hair follicle to both chemical and thermal destruction through the use of galvanic and low-intensity high-frequency currents, respectively. Although the combination treatment is slower, it is significantly more effective than the individual use of each method and is less painful (24,25).

While pain tolerance to electrolysis has been shown to develop over several sessions (26), the use of topical anesthetics can decrease treatment pain significantly (30). Correct needle placement is relatively painless; however, premature or delayed activation of the electrode during its insertion or withdrawal may produce pain as well as damage the superficial skin which could lead to scarring (27). Electrolysis is more effective on anagen hairs; therefore, shaving within a few days before electrolysis greatly increases its efficacy because it ensures that only growing anagen hairs are epilated (26,28). This is particularly important during the initial treatment of an area because as many as 60% of the hairs may be in telogen which are difficult to eradicate permanently. Hair regrowth rates following treatment are highly variable and range from 15–50% (31–34). The wide variation has been attributed to the differences in equipment used and to the skill of the operator. Multiple treatment sessions are necessary due to the practice of avoiding simultaneous treatment of adjacent hair follicles (within 3–4 mm of each other) in order to reduce unnecessary thermal skin injury. As many as 100 hairs can be removed in 20 minutes with thermolysis (27).

Infectious diseases potentially transmissible through electrolysis include bacterial and viral infections such as impetigo, verrucae, molluscum contagiosum, and herpes simplex (HSV) (5,35). As such, the area of skin to be treated should be completely examined and clear of bacterial and viral infections prior to treatment in order to avoid autoinnoculation (5). For patients at known risk of HSV reactivation, prophylactic oral antiherpetics should be considered for upper lip or chin treatment.

While relatively rare, other contagious skin diseases such as leprosy, syphilis, tuberculosis, acquired immune deficiency syndrome, and hepatitis can also be spread from one patient to another through electrolysis (5). Electrolysis needles must be of either the prepackaged sterile disposable type or sterilized with the steam autoclave, chemiclave, or dry heat and stored to ensure sterility prior to use. The use of unsterilized and/or reusable electrolysis needles could lead to these infections and, thus, are contraindicated (5,26).

Underlying medical conditions should be determined in patients undergoing electrolysis, including history of bacterial endocarditis, heart valve surgery or anomalies, and presence of cardiac pacemakers or joint prostheses. Antibiotic prophylaxis in patients at high risk for the development of bacterial endocarditis as well as in patients with prosthetic devices should be considered (36,37). Short bursts of electric current

(< 5 seconds) are generally safe in patients with cardiac pacemakers; however, as a precaution, peripheral pulse or cardiac monitoring is suggested. True galvanism is considered safe in the presence of cardiac pacemakers and is most often used by nonmedical personnel (5,27).

Patients who are prone to hypertrophic scarring, keloids, postinflammatory hyperpigmentation, or other cutaneous dyschromias should be advised that these complications may result from electrolysis treatment. Of particular risk are scar-prone areas of the face such as the mandible and upper lip (5). Pigment tattooing has also been described as a complication of electrolysis (38,39). Other drawbacks include the discomfort, cost, and extensive time necessary for each treatment session (21,40,41).

Autoelectrolysis is a heavily advertised method of home electrolysis that usually involves the use of a galvanic device. It has been declared unsafe by the British Medical Association and has been noted to be unsatisfactory due to its difficulty of use and associated treatment pain and scarring (42,43). The electric tweezer, erroneously believed by some as a permanent means of hair removal, has declined in use following the FDA's report that it is "no better than nonelectrified household tweezers" for hair removal (44).

Recently, an over-the-counter device for personal use has been developed to thermally remove unwanted hair (45). The hand-held self-treatment device (no!no! Thermicon™, Radiancy Inc, Orangeburg, NJ) uses the principles of thermal transference to heat the hair shaft through a thermodynamic wire. This device is purported to remove unwanted hair from all parts of the body excluding the face, ears, neck, and genitalia.

Lasers

Laser surgery permits satisfactory treatment of large areas of unwanted excess hair with less discomfort than electrolysis or thermolysis and fewer complications (27). The improved clinical results are made possible by the high specificity and selectivity of the laser systems to pigment-containing hair due to the use of an appropriate wavelength of light with the proper pulse energy and duration. Thermal injury is restricted to the target hair follicle and the scarring potential is effectively reduced by applying the theory of selective photothermolysis whereby a given target is capable of absorbing light of a particular wavelength in an amount of time that is less than or equal to the thermal relaxation time of the target (46). The targets in this case appear to be hair follicle germinal cells that reside at the bulge and the bulb.

In order to selectively target the hair follicle, light can be absorbed by a normal component of the follicle such as melanin or keratohyalin. An alternative technique is to use an exogenous material or chromophore that will be absorbed by the hair or placed in the follicular orifice to absorb the light (27). The latter technique is exemplified by the patented *SoftLight* process which uses a Q-switched neodymium:yttrium-aluminum-garnet (QS Nd:YAG) laser to target a topically applied carbon-based solution that has presumably penetrated the hair follicle. The carbon particles within the follicle absorb the infrared 1064 nm light and undergo a rapid temperature increase. The thermal energy results in selective injury to the germinative cells of the follicle that are in contact with the solution. The shock wave produced by increasing temperature causes mechanical damage to the hair follicle, delaying hair regrowth. Anesthesia is not generally used although topical anesthetic creams can be applied prior to treatment. A single Nd:YAG laser treatment results in delayed hair regrowth for up to 3 months (47,48). Topical application of carbon solution has not been proven to be statistically more effective than using the laser alone, particularly in patients with dark terminal hairs (47). Incomplete elimination and eventual hair regrowth are thought to be due to incomplete follicular damage. Multiple treatment sessions timed so that the treated hairs are in anagen phase may further reduce hair regrowth. Minimal immediate edema and transient erythema may be seen for the first 24–48 hours post-treatment. Infrequently, postinflammatory hyperpigmentation that resolves in less than 6 months may occur, and even more rarely, petechiae may be seen for a few days postoperatively. In the majority of cases; however, few associated side effects are observed and no scarring has been reported.

The melanin-based selective photothermolysis process of long-pulsed infrared laser irradiation is also a popular noninvasive modality for hair removal. The laser light is selectively absorbed by endogenous melanin followed by thermal necrosis limited to the follicular zone. The amount of melanin present in the follicular epithelium and papillae appears to be a sufficient chromophore for light absorption in the follicle (27,49).

Several normal-mode (non-Q-switched) high-energy, pulsed ruby (694 nm), alexandrite (755 nm), and diode (800 nm) lasers are currently available that are designed to target melanin in unwanted hair follicles (Table 2). Some systems have specially

Table 2. Hair removal lasers and light sources

Laser and light sources	Wavelength (nm)	Pulse duration
Long-pulsed ruby lasers	694	1–3 ms
– Chromos™ 694 (SLS Biophile, Ltd, Carmarthenshire, UK)		
– EpiLaser™ (Palomar Medical Technologies, Inc., Burlington, MA, USA)		
– EpiTouch™ Ruby (ESC Sharplan, Norwood, MA, USA)		
– Palomar E2000™ (Palomar Medical Technologies, Inc., Burlington, MA, USA)		
Long-pulsed alexandrite lasers	755	2–20 ms
– Apogee 5500™ (Cynosure, Inc., Westford, MA, USA)		
– Arion™ (WaveLight Technologies AG, Germany)		
– GentleLASE® (Candela Corp., Wayland, MA, USA)		
– UltraWave™ Alexandrite (Adept Medical Concepts, Rancho Santa Margarita, CA, USA)		
Diode lasers	800–810	5–400 ms
– Comet™ (Syneron Medical Ltd, Yokneam, Israel)	810 nm diode and radiofrequency	
– F1 Diode Laser™ (Opusmed Inc., Montreal, Canada)		
– HR-Force (Alderm, N.A., LLC, Irvine, CA, USA)		
– LightSheer™ (Lumenis Inc., Santa Clara, CA, USA)		
– Lumenis One LightSheer™ (Lumenis Inc., Santa Clara, CA, USA)		
– Sonata™ (Orion Lasers, Fort Lauderdale, FL, USA)		
– VariLite™ (Iridex corp., Mountain View, CA, USA)	532 nm KTP and 940 nm diode	
Q-switched Nd:YAG lasers	1064	5–20 ns
– MedLite® IV (ConBio, Dublin, CA, USA)		
– MedLite® C6 (HOYA ConBio™ Medical & Dental lasers, Fremont, CA, USA)	532 nm and 1064 nm	
– RevLite™ (HOYA ConBio™ Medical & Dental lasers, Fremont, CA, USA)	532 nm and 1064 nm	
– SoftLight™ (Thermolase, San Diego, CA, USA)		
Long-pulsed Nd:YAG lasers	1064	5–250 ms
– Apogee Elite™ (Cynosure, Inc., Westford, MA, USA)	755 nm alexandrite and 1064 nm Nd:YAG	
– ClearScan™ (Sciton Inc., Palo Alto, CA, USA)		
– CoolTouch VARIA™ (CoolTouch Inc, Roseville, CA, USA)		
– CoolGlide® CV (Cutera Inc., Brisbane, CA, USA)		
– CoolGlide® Excel (Cutera Inc., Brisbane, CA, USA)		
– CoolGlide Vantage® (Cutera Inc., Brisbane, CA, USA)		
– Dualis^{VP} (Fotona Medical, Slovenia)	532 nm KTP and 1064 nm	
– Dualis^{XP} (Fotona Medical, Slovenia)		
– Fidelis^{XP} (Fotona Medical, Slovenia)		
– FriendlyLight® Nd:YAG (Aerolase™, Tarrytown, NY, USA)		
– Gemini™ (Laserscope, San Jose, CA, USA)	532 nm KTP and 1064 nm	

Table 2. *Continued*

Laser and light sources	Wavelength (nm)	Pulse duration
– GentleYAG® (Candela Corp, Wayland, MA, USA) – Lyra-i™ (Laserscope, San Jose, CA, USA) – Lumenis One Multi-Spot™ Nd:YAG (Lumenis Inc., Santa Clara, CA, USA) – Mydon™ (WaveLight Technologies AG, Germany) – Profile MP™ 1064 Module (Sciton Inc., Palo Alto, CA, USA)		
– UltraWave™ II, III (Adept Medical Concepts, Rancho Santa Margarita, CA, USA)	755 nm alexandrite and 1064 nm	
Intense pulsed light (IPL) – Aurora DS™ (Syneron Medical Ltd, Yokneam, Israel) – Clareon HR™ (Novalis Medical, Tampa, FL, USA)	590–1400	2.5–5 ms
– Cynergy III™ (Cynosure, Inc., Westford, MA, USA) – EpiCool Platinum-HR™ (OptoGenesis™, Austin, TX, USA) – EsteLux™ (Palomar Medical Technologies, Inc., Burlington, MA, USA) – Galaxy DS™ (Syneron Medical Ltd, Yokneam, Israel) – Lumenis One Universal IPL Module™ (Lumenis Inc., Santa Clara, CA, USA) – MediLux™ (Palomar Medical Technologies, Inc., Burlington, MA, USA) – McCue™ Variable Pulsed Light System (Adept Medical Concepts, Rancho Santa Margarita, CA, USA) – McCue Ultra VPL™ (McCue Corp, Inc., Belton, MO, USA) – Novalight™ FPL (American Medical Bio Care, Inc., Newport Beach, CA, USA) – Omnilight™ FPL (American Medical Bio Care, Inc., Newport Beach, CA, USA) – Profile MP™ (Sciton Inc., Palo Alto, CA, USA) – Profile BBL™ (Sciton Inc., Palo Alto, CA, USA) – Quadra Q4™ Platinum Series (DermaMed USA, Inc., Lenni, PA, USA) – SkinStation™ (Radiancy, Inc., Orangeburg, NY, USA) – Silk'n™ (Home Skinovations, Ltd, Israel) – Solarus HR™ (Novalis Medical, Tampa, FL, USA) – Solis™ (Laserscope, San Jose, CA, USA) – SpectraPulse™ (Adept Medical Concepts, Rancho Santa Margarita, CA, USA)	595 nm pulsed dye, 1064 nm Nd:YAG, and 500–950 nm pulsed light	
– StarLux™ (Palomar Medical Technologies, Inc., Burlington, MA, USA)	1064 nm Nd:YAG and 500–670 nm/ 870–1400 nm pulsed light	

designed contact cooling handpieces that minimize thermal injury to the pigmented epidermis by lowering the skin surface temperature and maximizing the intensity of light in the deeper dermis. Similarly, other laser systems require either the topical application of a chilled transparent gel or the simultaneous air or cryogen cooling devices to achieve epidermal cooling during treatment

FIG. 1. Terminal facial hair growth before (top) and 6 months after third long-pulsed 755-nm alexandrite laser treatment (delivered at monthly time intervals) (bottom). Similar results would be expected with the use of other long-pulsed infrared lasers (694-nm ruby or 800-nm diode) and intense pulsed light sources.

(50). Shaving the hair-bearing site is performed preoperatively in order to prevent conduction of thermal energy to the adjacent epidermis from overlying hairs. While topical anesthesia can be used, it is not routinely needed, as epidermal cooling helps to decrease laser-associated discomfort. A 2- to 6-month growth delay is typically observed after a single infrared laser treatment. Observed hair regrowth is more sparse and individual hairs are thinner and paler in color (FIG. 1). Side effects include mild discomfort, transient erythema and edema and, rarely, skin dyspigmentation, crusting, and vesicular formation. The incidence of pigmentary alteration and vesiculation increases in tanned skin and in those patients with darker skin phototypes. Neither permanent dyspigmentation nor scarring has been reported when appropriate laser parameters and techniques are applied (51).

In general, the energy density necessary to coagulate a hair follicle is dependent on the hair shaft color, its diameter, and depth (52). Hair shafts of lighter color and smaller diameters generally require the use of higher energy densities and/or the application of an exogenous chromophore (e.g., topical carbon suspension). A drawback to using shorter infrared wavelengths (e.g., 694 nm ruby) is that a more deeply pigmented epidermis impedes laser radiation penetration of the dermis. Thus, the amount of light that reaches the hair bulb is reduced with a decreased effect on the germinal cells. In addition, unwanted epidermal injury may occur, causing hypopigmentation. Thus, the ideal treatment candidate for selective laser-assisted hair removal should have untanned, pale skin (phototypes I–II), and dark hair. Patients with darker skin tones (Fitzpatrick skin phototypes IV–VI) should only receive laser treatment with either lower fluences of alexandrite and diode laser wavelengths or with a long-pulsed Nd:YAG laser which can safely deliver its longer 1064 nm wavelength to avoid unwanted postoperative skin dyspigmentation (21,53–55).

One notable side effect of laser-assisted hair removal is the stimulation of new hair growth within previously irradiated areas or in close proximity to the treatment regions (56). This "paradoxical effect" has been seen after treatment with each of the laser and light hair removal systems. Its development has been attributed to activation of dormant hair follicles by either the application of subthreshold fluences or the conduction of heat to surrounding areas which eventuates in synchronization of the hair growth cycle (57).

Nonlaser light sources

Noncoherent light sources have also been used for hair removal (58,59). Flashlamp-generated intense pulsed light at wavelengths longer than 590 nm has been shown to selectively injure hair follicles to effect hair removal. Similar clinical responses to those outlined with the long-pulsed infrared laser systems have been reported. Because a variety of wavelengths can be generated with intense pulse light systems, it may be possible to treat darker skin tones without significant dyspigmentation.

Removing hair with in-office laser- or light-based treatments is expensive and requires multiple treatment sessions. Recently, a novel, low-energy, pulsed-light device for home-use hair removal (Silk'n™, Home Skinovations Ltd, Yokneam, Israel) has been developed to overcome these disadvantages (FIG. 2). This device is composed of two flashlamps in a hand-held applicator (optical filter 475–1200 nm, fluences up to 5 J/cm^2). Although not a replacement for in-office laser and light-based treatments, the device has been shown to be a safe and relatively effective at-home hair removal treatment option in patients with various skin phototypes (60).

Photodynamic therapy

Photodynamic therapy with topical application of aminolevulinic acid (ALA) followed by red light exposure has also been used for the destruction of excess or unwanted hair (61). ALA induces the follicular synthesis of the potent photosensitizer,

FIG. 2. A novel hand-held intense pulse light device is the latest innovation for home hair removal.

protoporphyrin IX (62). Prior to treatment, hair is first wax-epilated and then an ALA-containing lotion is applied to the skin surface. Over several hours, the ALA is more selectively absorbed in the hair follicles than in the epidermis. The treatment site is then exposed to red light that activates the photosensitizer, causing cell membrane damage from the creation of singlet oxygen. A 40% decrease in hair regrowth has been reported 6 months after a single treatment (61,62). Using PDT, it is possible to treat large areas independent of skin or hair color. Because the method is still in the developmental stage, further studies are needed to determine its long-term safety and efficacy.

Summary

The presence of excessive hair can be a source of distress that can lead to such psychological problems as anxiety, depression, and reduced quality of life. Affected patients are amenable to either cosmetic procedures or medical treatment. Current methods of hair removal include topical eflornithine, shaving, waxing, depilatories, electrolysis, and laser and light-based devices. Unfortunately, no single treatment method can achieve complete hair eradication in every skin and hair type.

The use of lasers and light sources permit expedient treatment of larger areas of skin with minimal discomfort. In addition, the selectivity and therefore effectiveness of these methods are less operator-dependent than other modes of therapy. Their noninvasive, needle-free nature greatly reduces the risk of disease transmission and scarring. Although prolonged hair growth delay is evident after laser use, additional studies are needed to assess the appropriate number and timing of treatment sessions in order to obtain even longer and, perhaps, permanent hair removal.

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