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Hair removal using a combination of conducted radiofrequency and optical energies–an 18-month follow-up

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OBJECTIVE: Multiple lasers and intense pulsed light sources have been shown to provide long-term hair removal; however, the management of all dark skin phenotypes and light-colored hair remains problematic. The present study examined the long-term photoepilatory effect of a combined intense pulsed light (IPL) (680–980 nm)/radiofrequency (RF) (10–30 J/cm^3) light source and its efficiency for the treatment of multiple skin phenotypes and varied hair colors.
METHODS: Forty adult patients (skin phenotypes II–V) with varied facial and non-facial hair colors were treated with a combined IPL/RF technology. Four treatments were carried out over a period of 9–12 months at 8–12-week intervals. Light energy ranged from 15 to 26 J/cm^2, while RF energy varied from 10 to 20 J/cm^3. Hair counts and photographic evaluation of skin sites were obtained at baseline, and months 1, 3 and 5 after the final treatment session. H&E biopsies were examined at 1 week in five randomly selected study cohorts.
RESULTS: Maximum hair reduction was observed at 6–8 weeks after each treatment. An average clearance of 75% was observed in all body locations at 18 months. No significant adverse sequelae were reported. Results showed no significant dependence on skin color: lighter and darker skin types responded similarly to treatment. Histologic evaluation revealed thermal damage to hair follicles with vacuolar degeneration.
CONCLUSION: The combined IPL (680–980 nm)/RF light source with contact cooling is a safe and effective method of long-term hair reduction in patients of diversified skin types and varied hair colors and is associated with excellent patient safety.
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Introduction

In the past decade, intense pulsed light (IPL) and laser light sources have proved to be effective for long-term hair removal.[1–8] A high efficiency for dark hair and a relatively low risk of adverse effects, together with the ability to treat large areas rapidly, have made photoepilation the number one procedure in aesthetic medicine. The main requirement for these devices is the selective thermal destruction of hairs mediated by melanin-induced absorption of the light in the hair shaft, while the epidermis and surrounding tissue absorb light at minimal levels.[9,10] There are a number of technologies described in the literature for photoepilation of light hair phenotypes, including a number of short wavelength lasers (long-pulsed ruby (694 nm) and alexandrite (755 nm)). Versatile intermediate wavelength technologies, including the diode (800 nm) and IPL sources (500–1200 nm), may target

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many varied hair and skin phenotypes. Long wavelength technologies, including the 1064 nm Nd:YAG, have been utilized for the treatment of dark skin, dark hair phenotypes.[11–15]

Although most hair types have benefitted from the presently available technologies, the treatment of blond and white hair has been particularly problematic due to the low intensity of target melanin chromophore in the targeted follicles.[16–19] The present study examined the long-term photoepilatory effect of a new technology which combines an IPL source (680–980 nm), producing optical energies as high as 30 J/cm^2 with pulse durations as high as 120 ms, with a bipolar radiofrequency device, which can generate radiofrequency (RF) energy as high as 20 J/cm^3 with a pulse duration as long as 120 ms, designed to deliver RF electrical current at a depth of 4 mm which can target deep-lying hair follicles for long-term photoepilation (Aurora Syneron Medical, Yokneam, Israel). The theory behind this technology is to decrease optical energy to a level that is safe for all skin types while compensating for the lack of light by utilizing an additive energy that is not optical, but is selectively absorbed by the hair structure.

Materials and methods

Forty adult patients (aged 18–46 years), mean age 38, skin phenotypes II–V (Table 1) with various hair colors, were included in the study (Table 2). A variety of facial and torso body sites were chosen for the study (Table 3). The face was the most prevalent site treated and studied. Patients were screened for recent sun exposure (tanning), endocrinopathy (androgenic or thyroid dysfunction) and isotretinoin usage. History of previous laser treatments or electrolysis was also an exclusion criterion. Waxing, bleaching and depilatory agents were discouraged for 4 weeks prior to therapy.

Skin type	Number of patients
II	11
III	10
IV	12
V	7

Table 1
Phenotype characteristics of the combined IPL/RF study population (n = 40).

Hair color	Number of patients
Black	16
Brown	13
Blond	5
Red	3
White	3

Table 2
Hair color for the combined IPL/RF photoepilation study group (n = 40).

Site	Number of patients
Facial	10
Bikini line	7
Axilla	7
Legs	8
Trunk	8

Table 3
Anatomic treatment locations for the combined IPL/RF study group (n = 40).

Informed consent from all participants was obtained and the body site to be treated was identified and photographed. No topical anesthetic agent was applied to treated body areas.

The target area was shaved prior to treatment. Sequential digital photographing using identical lighting, patient positioning and camera equipment (Fujifilm FinePix S2 Pro Digital SLR Camera, Tokyo, Japan) was obtained of all treatment sites at baseline, and 1, 3 and 6 months after the last treatment.

The study group of patients received four treatments over a period of 9–12 months at 8–12-week intervals (results were monitored to 18 months after the first treatment or six months after the last treatment). A thin layer of transparent gel was used for cooling and skin hydration. Light pressure was applied via the applicator to the treatment site in order to ensure good coupling of electrodes to the skin surface. In the study protocol, the light energy range varied from 15 to 26 J/cm^2, set according to patient skin color phenotypes. On patients and/or body sites with darker skin types, lower optical energy was used, while higher optical energy was used on patients and/or body sites with lighter skin and hair color. Since RF energy is equally efficient for all hair color and not sensitive to skin color, different guidelines were utilized: over lower body areas or skin with dense hair, a lower RF energy was used – typically 10–14 J/cm^3; in all other areas a higher RF energy of 18–20 J/cm^3 was employed. Contact cooling (-5°) was incorporated into the treatment tip.

Two separate hair counts by independent observers using a 10× illuminated magnifier were performed within a well-defined 3 cm^2 region. The following reference landmarks were utilized in order to achieve uniformity of sequential hair units: face (pre-auricular sulcus), bikini line (inguinal area), axillae (mid-axillary line), legs (prepatellar notch) and trunk (mid-spine).

Percentage hair reduction was defined as the average number of terminal hair present 1, 3 and 5 months after treatment compared with the average number of terminal hairs at baseline. Subjective patient reports and adverse effects were also recorded at each follow-up visit.

Punch biopsies of 4 mm were taken in five individuals 1 week following treatment in order to evaluate changes to histologic results occurring after IPL/RF pilosebaceous interaction.


(A) (B)

Figure 1
(A) Before combined intense pulsed light/radiofrequency (IPL/RF) hair removal; (B) after combined IPL/RF hair removal (four treatments; 6 months following last treatment; brown hair; 85% hair removal efficiency).

Site	Average clearance
Axilla	85%
Bikini line	75%
Legs	85%
Trunk	65%
Face	65%
All anatomic locations	75%

Table 4
Mean hair removal efficiency (MHRE) by anatomic location after four treatment sessions.

Hair color	Average clearance
Black	85%
Brown	80%
Blond	60%
Red	60%
White	40%

Table 5
Mean hair removal efficiency (MHRE) by hair color after four treatment sessions.

Results

During the first week after treatment, no significant hair reduction was observed. Maximum reduction in hair was observed at 6–8 weeks after each treatment.

Hair density decreased from treatment to treatment as noted by both patients and investigators. Final clearance results in different anatomic body locations are presented in Table 4. An average clearance of 75% was observed at all body locations at 18 months. Results showed the best decrease of 85% for the axillae and legs (Figures 1 and 2).

Other than mild erythema observed in 20% of the treated patients, which resolved within 1 day post-treatment, no significant adverse events were noted at each of the follow-up visits.

Results showed no significant dependence on skin color, as lighter and darker skin types responded similarly to treatment (Table 4). As expected, darker hair phenotypes provided greater hair removal efficiency (Table 5).

Histologic evaluation of hair follicles revealed thermal damage to hair follicles with vacuolar degeneration at 3.5 mm noted 1 week following treatment (Figure 3).

Discussion

There are two kinds of light source that provide energy at high enough levels in order to achieve pan-thermal destruction of


(A) (B)

Figure 2
(A) Before combined intense pulsed light/radiofrequency (IPL/RF) hair removal; (B) after combined IPL/RF hair removal (four treatments; 6 months following last treatment; black hair; 90% hair removal efficiency).

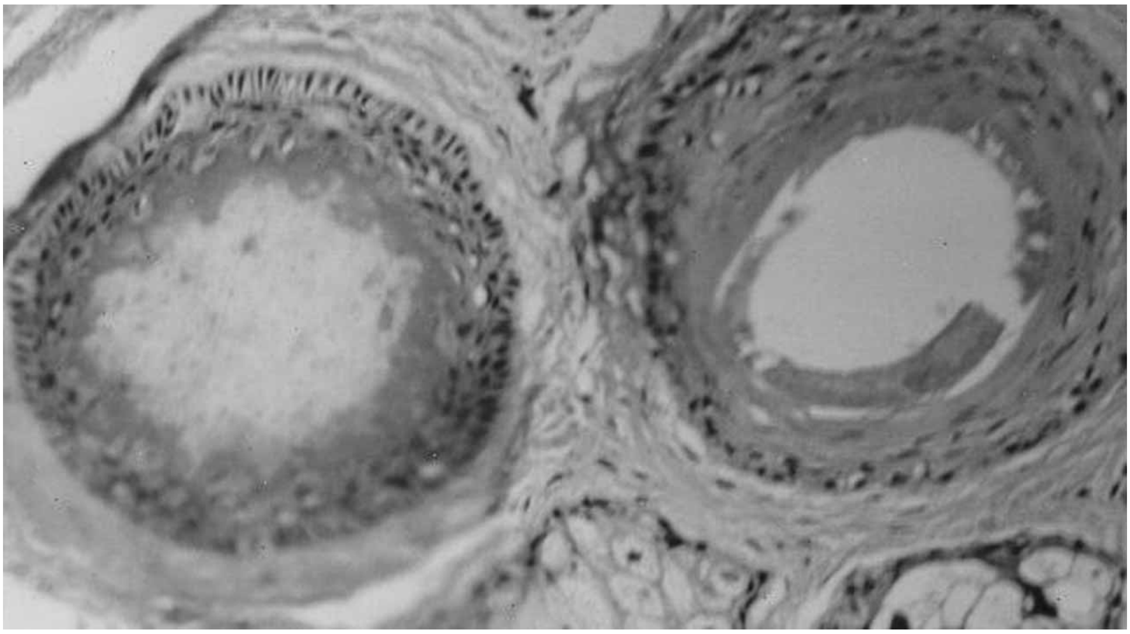

Figure 3
H&E of hair follicles revealed thermal damage to hair follicles, with vacuolar degeneration at 3.5 mm noted 1 week following treatment (magnification ×80).

hair follicles: lasers and IPLs. In general, owing to the melanin absorption curve when longer wavelengths are used, both the treatment efficacy and safety improves.[16] Melanin, the chromophore that gives hair its color and absorbs light, is present in the epidermis. Both cooling and long-pulse durations play important roles in decreasing epidermal heating with minimal impact on treatment results, as they allow the application of higher fluences of energy.[20]

Recently, the long-pulse 1064 nm Nd:YAG laser has been found to be useful for hair removal in all skin types.[21–28] This wavelength is not well absorbed by melanin of the epidermis or hair shaft. To compensate for the lower absorption level and therefore lower heat generation, higher energy levels must be utilized at longer pulse durations in order to maintain safety. However, the methodology is somewhat limited as pulse duration cannot be increased infinitely because if it exceeds the target thermal relaxation time, the heat will dissipate to the surrounding tissue and will not be localized around the hair shaft.

The technology presented in this study utilizes electrical optical synergy (ELOS), a new approach combining IPL (optical) and conducted RF modalities simultaneously applied to tissue.[29] Its advantages in initial clinical trials show results in areas where purely light-based systems have not shown significant efficacy; that is, in the treatment of light hair and dark skin phenotypes. Both forms of energies are pulsed and delivered to the tissue with a hand-held applicator. The light source is a high-power xenon lamp that is filtered to transmit the wavelength range of 680–980 nm. The conducted RF electrical energy is bipolar and can generate energy up to 20 J/cm^3. RF current flow in the tissue may be explained by the following equations.

Distribution of electrical current is described by the continuity equation:

$$div\, j = 0 \tag{1}$$

according to Ohm equation:

$$J = \sigma E \tag{2}$$

where E is electric field strength, which is described by the following equation:

$$E = grad\varphi \tag{3}$$

where φ is a potential of an electric field.

Combining equations (1)–(3), the following equation for the potential of an electric field can be obtained:

$$Div(\sigma grad\varphi) = 0 \tag{4}$$

The numerical solution of equation 4 is presented in Figure 4 for a bipolar geometry with electrode distance of 8 mm.

The maximum current density is on the electrode surface in contact with the skin. Current density decreases with the distance from the electrode contact points. As can be seen from Figure 4, the penetration (where the RF current is 1/e from the maximum value) is 4 mm.

The basis for the design of the RF electrodes is to deliver the RF electric current to a depth of 4 mm, which can target the deepest hair follicles in all anatomic locations (Figure 5). In theory, by using the different types of energies, we can reduce the optical energy to a safe level that can be used even on darker skin phenotypes (i.e. Fitzpatrick V and VI). Treatment efficacy is not compromised, as shown in the present study where 75% of long-term mean hair removal efficiency (MHRE) at 14 months is similar to that reported with other light-based technologies because of the use of additional conducted RF energy that selectively heats the hair follicle. The conducted RF selectivity mechanism is not based on melanin absorption, and therefore is not sensitive to skin or hair color.

It should be noted that the theory behind the technology presented here is based on the principle of selective thermolysis

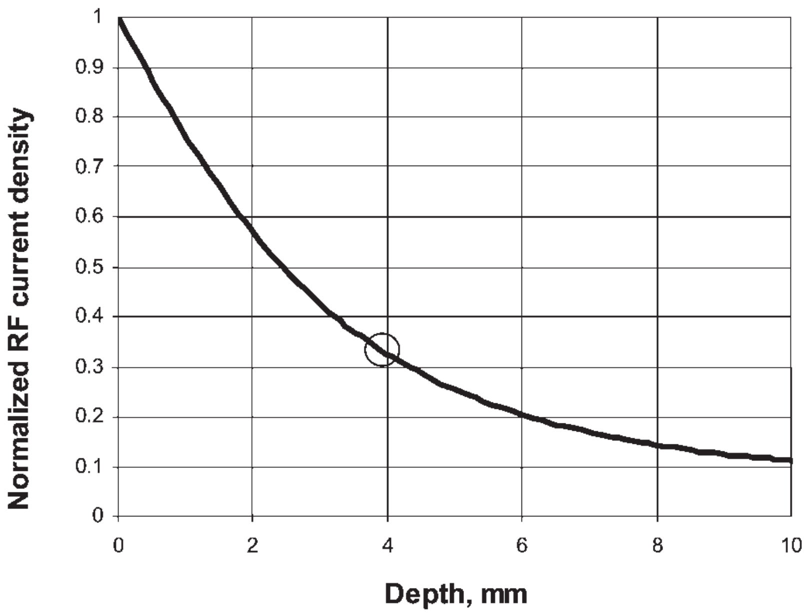

Figure 4
Radiofrequency current relative density as a function of depth, for a bipolar system with electrodes 4 mm apart. The circle represents the penetration depth.

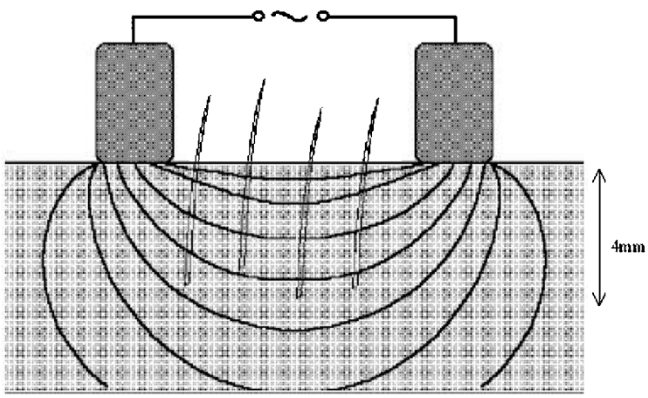

Figure 5
The geometry of the radiofrequency (RF) electrodes is designed to deliver the RF electric current at a depth of 4 mm, which can target the deepest hair follicles in all anatomic locations.

similar to other light-based technologies. However, in the present scenario, parameters of optical and RF energy (spectrum exposure duration and energy density) are chosen and optimized to selectively destroy hair follicles without damaging surrounding tissues. The light is absorbed and subsequently heats the hair shaft while the RF directly heats the hair follicle. The combination creates a uniform heat profile across the hair structure and potentially destroys it[9,10] (Figure 6).

These treatments were well tolerated by the subjects, none of whom utilized topical or other anesthesia. The only post-treatment side effect noted in the study population was transient erythema, which disappeared within 24 hours.

Conclusions

There are multiple lasers and light-based sources available for the treatment of unwanted hair. Two major

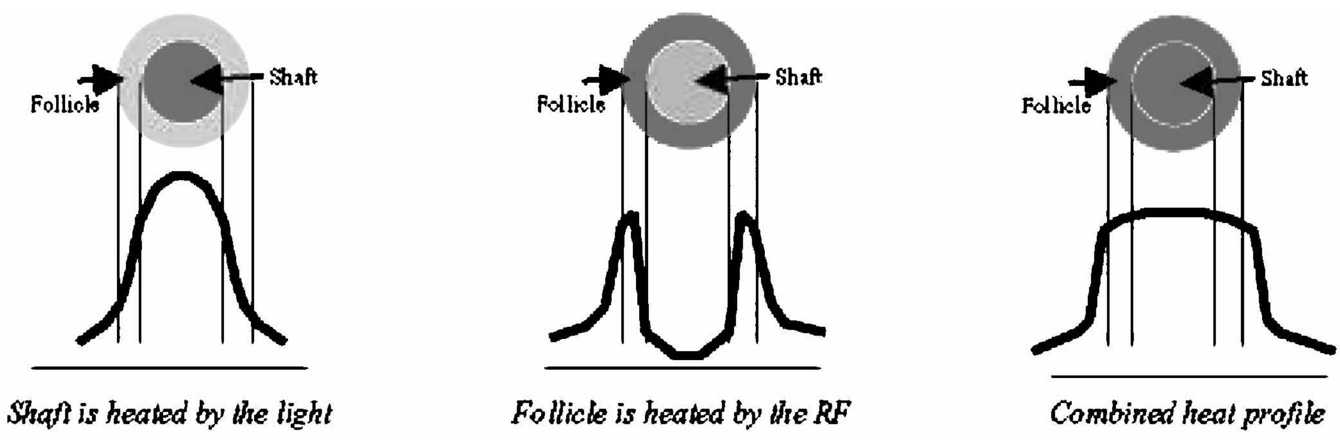

Figure 6
Temperature profile of the hair structure.

problematic areas include treatment of light hair hues and dark skin phenotypes. The findings reported in this study demonstrate that the combination of optical and electrical conducted RF energies may be synergistic and thus effective in providing long-term photoepilation in multiple skin phenotypes and varied hair colors with a high safety profile and minimal patient discomfort. Studies by the author presently in progress show this technology to be effective in the management of light blond and white hair phenotypes, although not with the same hair removal efficiency as noted in the present study.

In darker skin phenotypes, lower optical energies provide greater safety without sacrificing efficacy. In lighter colored hair, the synergistic effect of the two types of energy may play an important role.

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