Photo-Epilation using a broad-band intense pulsed light source: Luminette and Lumina

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Abstract

The use of the Lumina and the Luminette (Lynton Lasers Ltd, Wilmslow, Cheshire, United Kingdom) is discussed and the literature reviewed for hair removal applications. Clinical results for each of these applications show great promise with minimal (<0.5%) incidence of adverse side effects from over 10,000 hair removal treatments and high levels of patient satisfaction.

Introduction

There are various methods of long term hair removal which include shaving, waxing and electrolysis. In recent years, however, laser hair removal has grown in popularity. Photo-epilation (hair removal using light) has been shown to be very effective, arguably resulting in the most long lasting clearance of any hair removal treatment. The ruby laser was one of the first lasers to be utilised for this application but other systems such as Alexandrite or Nd:YAG have also shown good results [1]. Intense pulsed light systems which include Epilight (ESC) or the Lumina and Luminette systems (Lynton Lasers Ltd), have also proved to be very successful in this area of dermatology [2]. Long term hair removal using flashlamp systems has been reported to be relatively pain free and have minimal side effects whilst achieving excellent results.

Principle of Photo-epilation

In order to achieve long term hair loss the hair follicle itself must be damaged in order to inhibit re-growth. Irreversible thermal damage to the hair follicle is sufficient to prevent re-growth and is the goal of photo-epilation. The method utilised to heat the hair follicle relies on the absorption of light in the chromophore, melanin. Melanin is present in most hair shafts and, to a certain extent, the hair follicle itself. Melanin absorbs a broad range of wavelengths of light as shown by the absorption curve depicted in figure 1. Light directed at the skin is absorbed by the melanin in the hair shaft and produces heat which then conducts down the shaft and outwards into the surrounding follicle. If the heating effect is sufficient then the hair follicle is damaged to the extent that re-growth in inhibited and long term hair removal is achieved.

The key properties of the light required for successful photo-epilation are the wavelength, pulse duration and fluence. The ideal wavelength choice is derived from figure 1 and as the graph indicates, there is a broad range of suitable wavelengths. The wide absorption band of melanin means that the broad band spectral output of a flashlamp system is ideal suited for this application. The main consideration is to avoid unwanted absorption in blood or water.

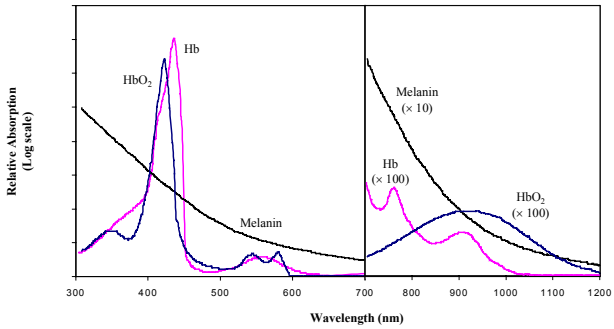

Figure 1: Relative absorption of melanin and blood (haemaglobin and oxy-haemaglobin). Adapted from Anderson and Parrish [3].

Most lasers successfully utilised for hair removal emit radiation with wavelengths avoiding the major absorption peaks of haemoglobin, ruby 694 nm, Alexandrite, 755 nm and diode 800 nm. The raw output from flashlamp systems covers a wide spectrum of wavelengths ranging from ultra violet to near infrared. The output therefore requires some form of filtration. The Luminette and Lumina, for example, have filtered outputs which results in an emitted wavelength range from 650 nm – 1200 nm. These wavelengths are readily absorbed in melanin but avoid the main absorption peaks of blood, therefore avoiding possibility of vascular damage.

The pulse duration (pulse width) should be equal to or less than the thermal relaxation time for the hair follicles. The exact thermal relaxation time for a hair follicle is impossible to calculate as there will be variations in sizes and shapes of the follicle (the physical size of an object is used to determine it's thermal relaxation time). However, it is generally thought that a pulse length of the order of tens of milliseconds is suitable. The majority of lasers and flashlamp systems used for epilation have pulse lengths which vary between 1 – 100 ms.

The fluence required to achieve follicular damage is largely determined from experiment and will often vary significantly depending upon various factors. The skin type (Fitzpatrick scale) and the colour of hair are major factors in determining a suitable fluence. However, there are also variations due to the parameters of a particular system, in general flashlamp systems require much higher fluences to achieve the same clinical results as a laser.

In order to understand this process it is important to understand the normal hair growth cycle which occurs in three distinct phases as shown below:

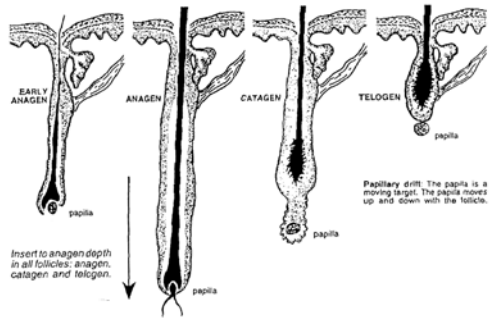

Figure 2: Growth cycle of hair

1. Anagen – the stage at which hairs are in active growth and attached to the papilla at maximum depth within the dermis

2. Catagen – the stage at which the hair growth is arrested but the hair continues to be nourished from the papilla

3. Telogen – the stage at which the hair growth creases altogether, the hair detaches from the papilla and contracts to almost one-third its original depth. The hair then falls out and the process begins once more with early anagen phase.

The percentage of hairs in each stage of the cycle, as well as the duration of each phase will vary for different body sites and for different people.

Probably the most important phase for laser assisted or flashlamp hair removal is early anagen, as the hair is connected to and nourished by the papilla, which is still relatively close to the surface. At this time it is possible to deposit sufficient energy into the hair shaft, the papilla and the hair bulb to cause permanent damage which will delay or prevent future hair re-growth. It is because of the need to treat hair in this early anagen phase that several treatments are always required to successfully target an entire area.

The use of lasers and flashlamp sources to remove hair depends on the absorption of laser light by the melanin contained in the hair in preference to absorption by melanin in the skin. As it is usual for melanin to exist in the epidermis, at the junction between the epidermis and the dermis, within the dermis as well as within the hair then the process can become quite complex. It is essential however that the hair is darker than the skin for preferential absorption to occur. The best results will normally be seen in patients with dark hair and fair skin. Cooling the skin before, during and after treatment can reduce damage to the epidermis.

Hair removal works by the process of **selective photothermolysis** as described earlier. This can be summarised as follows:

Hair in the early anagen growth phase is most susceptible to permanent damage.

↓

IPL source or Laser light of the correct wavelength is absorbed by the melanin in the hair follicle, which lies between 2mm and 5mm into the skin.

↓

This IPL source or laser light causes the hair follicle to heat rapidly, leading to destruction of the hair shaft and conduction of heat to the neighbouring cells.

↓

The cells responsible for re-growth of the hair are heated above 70°C and destroyed.

↓

New hair growth appears as hairs enter the anagen phase.

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New hair growth can be treated again and the % of re-growth decreases with each subsequent treatment.

The Luminette and Lumina

The process of photo-epilation is faced with a conflict between light absorption in the melanin found in the hair shaft and melanin existing around the epidermal/dermal boundary which varies in concentration depending upon the skin type. Dark skinned people (skin type V or VI on the Fitzpatrick scale) have a high melanin content in the skin whereas pale skin (skin type I or II) contains very little melanin. Absorption of light in the epidermal region will cause a heating effect that may result in undesirable tissue damage. The delivery of light from the Luminette and Lumina utilises a multi-pulse feature which aims to reduce the heating effect in the epidermis. The Luminette and Lumina both deliver light in a pulsed sequence, which allows a certain amount of epidermal cooling. The epidermis is able to cool more rapidly than a hair follicle in other words, the epidermis has a shorter relaxation time. The light is delivered in a pulse train which consists of a succession of short pulses with a delay between each one. The delay time is long enough to allow the epidermis to cool but it is short enough to have little cooling effect on the hair follicle. Thus over the entire pulse sequence (typically 3 – 5 pulses) the hair follicle increases in temperature yet the epidermis is able to remain cooler and a temperature differential is established which will damage the follicle without damaging the epidermis.

The Luminette and Lumina are both robust and powerful flashlamp system designed with the user in mind. The control of the Lumina has been made to offer the user pre-set suggested parameters with a simple to operate touch screen interface. The ergonomically designed hand-piece is comfortable to use and the three sizes of interchangeable light guides makes treatment of all areas easy. The Luminette is a smaller (desktop) system with simple yet effective control giving excellent results.

The results achieved using both the Luminette and Lumina for hair removal have been excellent for user and patient. The ease of use and the large area treatment head have significantly reduced treatment times for extensive areas such as legs or backs. Patients comments indicate that the Luminette and Lumina is relatively pain-free compared to other epilation treatments such as waxing or electrolysis with very little evidence of adverse effects. Following a treatment with the Luminette and Lumina many patients do not experience immediate hair loss but most find that the hair falls out within 10 days.

Using the Luminette or Lumina it is possible to remove over 50% of the hair in the anagen phase in a single treatment. Between 6 and 10 treatments correctly spaced, to target hair in the anagen phase each time, can therefore achieve 80-100% hair reduction. The expected time for which this degree of removal lasts may be up to 12 months or longer, although long-term studies are still be carried out to confirm this. Examples of the initial results from the Luminette and Lumina 650 treatments are shown below.

Figure 3: One month after first treatment the abdominal region of patient with skin type II and Brown hair shows vast improvement. Treatment parameters used were 3 pulses with a 30 ms delay between each pulse and a fluence which was varied between 18 – 24 J/cm^2.

Figure 4: Following one treatment the in-growing hairs on the neck have completely cleared. The patient (skin type II, dark brown hair) received treatment using 3 pulses with 40 ms delay time and a fluence varied from 18 – 22 J/cm^2.

Figure 5: The under arm of a patient with type III skin and dark brown hair 6 weeks after first treatment (4 pulses with 40 ms delay and a fluence of 12 – 16 J/cm^2).

New developments of the Luminette and Lumina [7]

The Lumina is also being clinically tested for the treatment of vascular lesions such as Port-wine stains (PWS) and leg veins. The treatment of vascular lesions, such as PWS, is dependent upon pulse length and wavelength. The wavelength selection must be such that the photons are readily absorbed by haemoglobin in order that the energy is deposited in the vessel to cause thermal damage to the offending veins [4,5]. The selection of wavelength with the Lumina system is dependent upon the chose of filter. Using a filter that allows a spectral transmission between approximately 550 nm – 1200 nm is suitable for vascular applications. The thermal relaxation time of various sizes of vessels found in vascular lesions would be ideally treated by varying light output pulse widths. The pulse length of the Lumina is variable and controlled (within certain physical constrains) only by the software allowing for ideal theoretical parameters to be tested or used in treatments.

Additional applications for the Luminette and Lumina flashlamp system include skin rejuvenation and combination facial therapy. Recent published work [6] indicates that flashlamp systems or lasers can be used to stimulate collagen growth in the dermis without damaging the epidermis. With the selection of suitable filters and pulse lengths the Luminette and Lumina will stimulate collagen growth without damaging the epidermis and are now being used to remove periocular and perilabial wrinkles. These treatments combined with traditional chemical peels open up a whole new area of cosmetic treatments and combination therapies for further development.

References

[1] S. H. Liew, R. Cerio, P. Sarathchandra, A. O. Grobbelaar, D. T. Gault, R. Sanders, C. Green, C. Linge, "Ruby laser-assisted hair removal: an ultrastructural evaluation of cutaneous damage" British Journal of Plastic Surgery **52**: 636 – 643 (1999).

[2] R. A. Weiss, M. A. Weiss, S. Marwaha, A. C. Harrington, "Hair Removal With a Non-Coherent Filtered Flashlamp Intense Pulsed Light Source". Lasers in Surgery and Medicine **24**: 128 – 132 (1999).

[3] R. Anderson, J. A. Parrish, "Microvasculature can be Selectively Damaged using Dye Lasers: A Basic Theory and Experimental Evidence in Human Skin". Lasers in Surgery and Medicine **1**: 263 – 276 (1981).

[4] D. W. Edstrom, A. M. Ros, "The treatment of port-wine stains with the pulsed dye laser at 600 nm". British Journal of Dermatology **136**: 360 – 363 (1997).

[5] D. Green, "Photothermal removal of telangiectasias of the lower extremities with the Photoderm VL". Journal of the American Academy of Dermatology, **38**, 61 – 68 (1998).

[6] D. J. Goldberg, K. B. Cutler, "Nonablative treatment of rhytids with intense pulsed light", Lasers in Surgery and Medicine", **26**, 196-200 (2000)

[7] J. Kenealy, "Applications and experience with the Lumina intense pulsed light system", British Skin Laser Study Group, May 2001