White Paper

Combining Single and Sequential Emissions of Wavelengths for Photoepilation of Hair, Treatment of Leg Telangiectasias and Treatment of Pigmentation

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Summary

Advances in aesthetic laser technology over the past two decades have allowed physicians to choose from a variety of fluences, spots sizes, pulse durations and wavelengths in treating hair, vascular lesions and pigmentation.

With the development of Multiplex (MPX), a proprietary technology that sequentially combines wavelengths to potentiate clinical effect, now clinicians have the ability to choose treatment with a single wavelength or a combination. Combining synergistic wavelengths in multiplex modality allows for a safer treatment profile with lower total fluence used to treat cutaneous pigmented and vascular lesions and for laser hair removal.

A second advancement has been integrated cooling which enables epidermal melanin protection while delivering treatment to the chromophore being targeted. The purpose of this article is to present a novel dual wavelength workstation employing multiplex technology which effectively treats hair, telangiectasias and lentigenes.

Introduction

Selective photothermolysis was introduced by Anderson and Parrish in 1983.¹, ² This is the core principal behind the science of laser technology. Chromophores are targeted by wavelength specific lasers delivered with a selected pulse duration that effectively destroys the target while sparing by standing tissue.

I. HAIR

Laser hair destruction was first noted by Dr. Leon Goldman in the 1960³, but it was not put to use for decades until the first photoepilation was attempted on human subjects in 1996.

By following the tenants of selective photothermolysis and understanding the science of optical irradiation and tissue interaction, the structures responsible for hair growth (bulge and the bulb) are targeted without damage to the epithelium.⁴, ⁵

Anatomy and Biology of Hair

The three primary components of the hair follicle are the infundibulum, isthmus and hair bulb. The hair bulb is located approximately 4 mm from the skin’s surface, and therefore the wavelength of the laser or light source selected must traverse this distance to effectively deposit energy at the follicle.⁶

The ability of the wavelengths within the optical spectrum of 600-1100 nm to damage the hair follicle is related to the type and amount of melanin located in the follicle. Melanin is found in the hair shaft, the outer root sheath of the infundibulum, and the matrix area.⁷ Pheomelanin is primarily found in red hair and does not absorb wavelengths of energy as effectively as eumelanin found in darker hair. If the follicle has diminished amounts of melanin, as seen in blonde or grey hair, then absorption within the optical spectrum of 600-1100 nm will be negligible.

Follicular melanocytes differ from epidermal melanocytes in that they contain more melanosomes. Keratinocytes in the epidermis have a ratio of one melanocyte per 25 keratinocytes, while the hair matrix has a ratio of 1:5.⁸ The increased ratio of melanocytes within the hair follicle is advantageous for laser hair removal.
Hair Cycle

The hair cycle is characterized by cyclical periods of growth and rest. The growth phase is termed anagen and the rest phase is telogen. The transition between growth and rest is catagen. During the different growth periods, the histological appearance of the hair follicle differs dramatically. The presence of melanin is highest during the anagen phase. During this phase, the follicle also penetrates the deepest in the skin, typically to the level of subcutaneous fat. Depending on the thickness of the skin, this depth can vary from 2 to 7 mm.

If shorter wavelengths are used solely during this period, the energy may not be delivered to the bulb, which would result in a lack of germinative cell damage correlating clinically to inefficient hair removal.

Mechanism of Hair Follicle Destruction

There are three basic mechanisms by which light can induce destruction in tissue.

1. Thermal destruction causes coagulation and vaporization due to local and preferential heating. This method of destruction is based on the principle of selective photothermolysis.

2. Mechanical destruction is a result of shock waves which cause violent cavitation due to extremely rapid thermal expansion. This involves the application of an external chromophore such as carbon in a topical suspension.

3. Photochemical injury is due to destructive oxidation by singlet oxygen or free radicals. This involves the administration of a photodynamic agent followed by exposure to light.

The primary target for the above mechanisms of destruction are the multipotential cells located in the bulge region of the follicle which play a vital role in the formation of new anagen hair follicles.

The Role of Wavelengths

Although melanosomes are vaporized at 694 nm through thermal confinement with low fluences, Ross et al. suggested that melanosome should be heated in a slower fashion to allow for greater thermal diffusion to the follicle, while still minimizing heat diffusion to the epidermis.

The 755 nm Alexandrite wavelength is less absorbed by epidermal melanin therefore the risk of epidermal damage is less than that seen with the 694 nm wavelength. The epidermis is further protected by an integrated cooling device. The effectiveness of the 755 nm Alexandrite laser for photo-epilation has been substantiated by many studies.

Color contrast between the epidermis and the hair shaft and bulb are critical in determining the optimal wavelength. For high contrast (dark hair, light skin), the 755 nm wavelength can be used with minimal risk of damage to the epidermis. For lower contrast patients (lighter hair and darker skin), the obvious choice would be the 1064 nm Nd:YAG. The 1064 Nd:YAG has a long wavelength which bypasses the epidermal melanin and delivers higher bulb-epidermal temperature ratio. This provides effective yet safe treatment options for Fitzpatrick skin types V and VI. This wavelength has also been shown to be effective in many studies.

A larger spot size and longer pulse duration increases clinical effectiveness by increasing depth of penetration and heat diffusion. Although quite effective for Fitzpatrick skin types V and VI, this wavelength can at times be painful to patients.
Multiplex Technology

The dual wavelength multiplexed laser (Elite MPX, Cynosure, Westford, MA) features sequential emission of the 755 nm wavelength and 1064 nm wavelength, which can be delivered from an array of handpieces (spot sizes from 3 mm to 18 mm). Both wavelengths can also be used in a standalone manner. The integrated air cooling system protects the epithelium during treatment. The computerized touch screen display allows for easy parameter changes, along with the ability to store frequently used settings.

The laser can deliver the 1064 nm wavelength first (or second depending on the selection chosen) to allow preheating of the follicle and coagulation of deep vasculature feeding the follicle, while the 755 nm targets the melanin within the follicle. This is important when treating patients that have undergone several treatments resulting in finer, thinner hair. The combination of wavelengths allows targeting of the follicle’s vascularity and melanin simultaneously for more precise targeting of the hair structures.

Also, the blending or sequential emission of wavelengths in multiplex mode allows for greater epidermal tolerance.

The 1064 nm Nd:YAG is an effective wavelength for treating course, dark hair regardless of skin type and is the wavelength of choice when treating darker skin types. In comparison, the 755 nm Alexandrite laser is excellent for almost all hair types with the exception of hair lacking pigment. The high epidermal absorption inherently found with the 755 nm wavelength limit the treatment darker skin types. The combination of the 1064 nm and 755 nm wavelengths can provide greater epidermal safety with excellent and prolonged hair reduction.

In a recent study, 22 subjects received four treatments four weeks apart to the axillary region. One axilla was treated with the Alexandrite wavelength while the other was treated with the Multiplex blends of either Alexandrite followed by Nd:YAG or Nd:YAG followed by Alexandrite wavelength at equivalent fluences. The side treated with the Alexandrite achieved approximately 80% clearance. The axillas treated with the Multiplex blend of Alexandrite/Nd: YAG achieved a clearance of 78% while the side treated with Nd: YAG followed by Alexandrite in the Multiplex mode achieved the greatest clearance of 85% at six months.

In another study, the author found that the blended 1064 nm Nd:YAG and 755 nm Alexandrite system is less painful than then the Nd:YAG system and the Nd:YAG system is more painful than the 755 nm Alexandrite system (EV. Ross, Abstract ASLMS 2007).

Overall, Multiplex Nd:YAG and Alexandrite is as effective as or more effective than the Alexandrite wavelength, while offering greater epidermal tolerance.
II. LEG TELANGIECTASIA

Leg veins are a cosmetic concern for a significant population of the general public. When assessing leg veins, it is important to decipher if the great saphenous vein is involved, in which case endovenous laser coagulation is recommended.

For reticular veins, sclerotherapy has been substantiated as an effective treatment modality. However, not all veins are amenable to cannulation, such as smaller spider veins. Patient phobia of needles and a higher rate of hyperpigmentation, telangiectatic matting and discomfort also make it difficult for a subset of patients.

Chromophore Targeting

Oxyhemoglobin (HbO₂) is the targeted chromophore in vascular lesions. It has a multi-peak absorption spectrum in the visible range of the electromagnetic spectrum at 410–429 nanometers (nm), 541 nm, and 577 nm. In addition to these absorption peaks, there is also a broad but less significant absorption peak in the red and near-infrared range between 700 nm and 1000 nm. ¹⁹

Although the pulsed dye laser has a greater coefficient of absorption for hemoglobin,²⁰,²¹ it can often be interfered with by another chromophore, melanin, which competes with hemoglobin for the absorption of the short wavelength.

With a slightly longer wavelength, such as the Alexandrite 755 nm wavelength, the ratio of absorption by hemoglobin is higher than by epidermal melanin.

While there is less hemoglobin absorption with the Alexandrite laser compared to the Pulsed Dye laser, the ratio of absorption by oxyhemoglobin is higher than by epidermal melanin; therefore there is less scattering and deeper beam penetration.²¹

When the 755 nm wavelength is compared to the 1064 nm (Nd:YAG), there is twice the photon absorption by hemoglobin with the 755 nm wavelength, allowing for a more effective vessel heating per J/cm² than at 1,064 nm.²²

The long pulsed Nd:YAG laser allows for deep penetration for treating dermal and subdermal vessels. It has a low coefficient of absorption for melanin therefore darker individuals can be treated. With Nd:YAG alone, high fluences must be utilized, thus creating a coagulum which can lead to intense patient discomfort.

Laser Considerations

Wavelength, pulse duration and spot size are the important parameters when considering laser vein treatment. Larger vessels tend to respond to longer wavelengths or the ratio of vessel-epidermal heating increases the probability of achieving complete vessel coagulation.²³,²⁴

With the dual wavelength system, the 7 mm spot size appears to give the best ratio of vessel heating to epidermal heating.

Sequentially Fired Alexandrite (755 nm) and Nd:YAG (1064 nm) wavelengths

With the dual wavelength laser, the Alexandrite and Nd:YAG laser can be utilized in multiplex mode. The Alexandrite wavelength theoretically penetrates to a depth of 2-3 mm and optimum parameters appear to be between 20-25 J/cm².²⁵

At this fluence, the 755 nm wavelength is fired first and converts the oxyhemoglobin to methemoglobin. The Nd:YAG is then fired in a sequential fashion. This exerts a greater effect because of its increased absorption coefficient for methemoglobin, resulting in less needed fluence to cause coagulation of the vein, correlating to less patient discomfort.

Because of the possibility of selecting longer wavelengths and longer pulse durations, epidermal protection is enhanced.
III. PIGMENTATION

Epidermal pigmented lesions are amenable to treatment with laser and light sources due to their superficial location. Many light-based modalities have been utilized, such as the erbium:yttrium aluminum garnet (Er:YAG) laser; the carbon dioxide (CO2) laser; the Q-switched Alexandrite, the ruby; the neodymium-doped yttrium aluminum garnet (Nd:YAG; 1,064 nm); and the frequency-doubled Nd:YAG (532 nm)2 lasers; and the 595-nm flash-pumped dye laser; the long-pulsed 532 nm Nd:YAG laser; and intense pulsed light.26, 27

Melanosome destruction occurs at pulse durations between 40 and 750 nanoseconds,28 however, the efficacy of lasers used for the treatment of cutaneous pigmentation depends on the localization of the pigment (epidermal, dermal or mixed), the way it is packaged (intracellular or extracellular) and the nature of the pigment (melanin).29

Although Q-switched Alexandrite lasers have traditionally been used to treat solar lentigenes, the smaller spot sizes and the time necessary to individually target the lesion can be quite inconvenient. The instant melanocytic destruction caused by Q switched lasers can damage normally pigmented epidermis contained within a treatment area which may lead to resultant post inflammatory hyperpigmentation.30

Alternatively, by utilizing a long pulse Alexandrite with 0.5ms pulse duration, solar lentigenes can be targeted effectively while sparing epidermal pigmentation. This treatment is performed by utilizing a small spot (5 mm) a 755 nm wavelength with a short pulse duration of 0.5 ms to effectively disrupt melanin, leading to eventual lightening.
Conclusion:
The Elite MPX provides the ability to perform aesthetic laser treatments with the 755 nm and 1064 nm wavelengths alone or sequentially fired in the proprietary Multiplex mode. Sequentially firing both wavelengths in Multiplex mode enables efficient and effective hair removal on all patients including those with resistant finer hair. The Multiplex mode also offers advantages for the treatment of leg telangiectasia and pigmentation.

References