Lasers In Facial Aesthetics - An Emerging Trend In Clinical Cosmetology

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Abstract

Lasers and optical technologies play a significant role in aesthetic and reconstructive surgery. The unique ability of optical technologies to target specific structures and layers in tissues to effect chemical, mechanical or thermal changes make them a powerful tool in cutaneous rejuvenation, hair removal, tattoo removal, fat removal and treatment of vascular lesions such as port-wine stains, among many other procedures.The constant improvement of existing applications and the emergence of novel applications such as photodynamic therapy, nanoparticles, spectroscopy and non-invasive imaging continue to revolutionize aesthetic medicine by offering a minimally invasive alternative to traditional surgery. Lasers and optical technologies are headed toward safer, easier and more quantifiable individualized therapy.

Key words: Facial aesthetics , Quality-switched (q-switched) laser, R20.

Introduction

Lasers, optical devices and related technologies play an increasingly significant role in aesthetic and reconstructive surgery. The most appealing feature of optical technologies is that their effects are localized to the region of light distribution, resulting in the ability to target specific structures and/or tissue layers within the skin or mucosal surfaces[1]. Furthermore, the tissue effects of these devices can be customized by adjusting the fluence rate, application time and spatial parameters. They allow precise control over the temporal and spatial evolution of heat and/or distribution of radiant energy to activate thermal, mechanical or chemical processes. This review seeks to offer a panoramic view of the history of optical technologies, highlighting essential developments as applied to facial plastic surgery in the last 15 years, later transitioning into a discussion of future trends and emerging optical technologies related to facial plastic surgery.

Biophysical Principles Of Dermatological Laser Therapy

In 1983 R. Rox Anderson and John A. Parrish[1] published their groundbreaking paper on the biophysical principle of laser therapy. Briefly, this principle of selective photothermolysis states that the efficacy of a medical laser relies on the specific absorption of radiation by distinct target chromophores. For lasers used in the dermatological practice, these chromophores are water (ablative lasers: the 2,940 nm Er:YAG-laser or the 10,600 nm CO_2-laser), haemoglobin (treatment of vascular structures: the long-pulsed 532 nm and 1,064 nm Nd:YAG-laser or the 585 nm pulsed dye laser), and melanin (treatment of pigmented structures: quality-switched systems, such as the 694 nm ruby laser, the 532 nm and 1,064 nm Nd:YAG-laser, or the 755 nm alexandrite laser; laser epilation: long-pulsed systems, such as 1,064 nm Nd:YAG-lasers).

Non-ablative laser systems emit radiation at wavelengths of approximately 500-1,200 nm, which allows the light deep enough into the skin to reach the target structures. This so-called optical window (~500–1,200 nm) is defined by the absorption of the epidermis/protein (<500 nm) and water (>1,200 nm).

The selective absorption of the monochromatic light emitted by the respective lasers, in the best case, enables us to generate a confined heating and hence, damage of the target chromophore, with no or minimal damage to the surrounding tissue. To achieve this optimal result, the pulse duration of our laser pulse should match the thermal relaxation time of the target. The thermal relaxation time is defined as the time that an object needs to dissipate 50% of the generated heat and depends on its diameter. Whereas larger structures (such as telangiectasia) are often treated with pulse durations of ≥30 ns, the small pigments require pulse durations of ≤80 ns, which can only be generated by quality-switched (q-switched) lasers. Ideally, these ultra-short, high-energy pulses (100–200 MW) do not only result in confined thermal damage but also generate a so-called photo-acoustic effect that disrupts the pigment into micro-fragments and/or releases it from cellular structures. Subsequently, these fragments are discharged via the epidermis or transported to the draining lymph nodes by tissue macrophages. This process takes approximately 4-6 weeks.

Application of Lasers & Optical Technologies

A. Skin Rejuvenation

1. Ablative Laser Therapy

Facial rejuvenation has long been the most highly desired aesthetic improvement, and the increased interest in skin rejuvenation has promoted rapid evolution of different methods to treat aged skin. Increasingly deep nasolabial folds and perioral wrinkles are the most significant signs of facial skin aging. Aging skin is characterized by excess rhytides and laxity. Over the past 10 years, a mainstay of skin rejuvenation has been laser resurfacing. Laser skin resurfacing was first described in 1985, following carbon dioxide (CO2) laser treatment of actinic cheilitis that unintentionally resulted in dramatic cosmetic improvement of the treated lip [2,3]. Laser skin resurfacing is ablative and relies on the selective photothermal destruction of specific layers of the epidermis and dermis combined with a limited or controlled depth of residual thermal injury. The interaction achieves thermal confinement, resulting in laser pulse durations that are shorter than absorbed photothermal energy dissipation time, an effect that promotes highly localized heating[4]. Heat induces dermal remodeling with new collagen synthesis and collagen contraction[5-7]. Ablative laser therapy has largely replaced the widespread use of chemical peels, which depend heavily on individual skin diffusion properties that are widely divergent among different facial regions and different people. In contrast, laser resurfacing produces fairly homogeneous and repeatable results. Laser skin resurfacing works best for patients with fair skin, while the results for patients with darker skin are less predictable and prone to pigmentary changes [8]. Ablative laser skin resurfacing treatments using lasers such as CO2 or Er:YAG have long been considered the gold standard for skin rejuvenation. For most pulse durations, the CO2 laser creates a zone of thermal injury up to 200 µm in depth, leading to prolonged erythema and slower recovery times. In contrast, the use of an Erbium:YAG laser (pulse length, approximately 250 microseconds) has advantages such as relatively quick recovery times ,much less erythema, higher light absorbance and the production of less thermal injury with each pass (approximately 50 µm) [9,10]. Resurfacing has also been performed using combinations of laser devices (eg Erbium:YAG and CO2 lasers), laser and botulinum toxin injections, laser and traditional facial plastic surgery procedures and laser and metallic-based skin care products[11-13.]

However, ablative laser treatments have become less popular due to prolonged downtime and an increased risk of complications with long-lasting side effects [14].

2. Non-ablative Laser Therapy

Methods that combine high efficacy with minimal downtime and minimal chance of side effects have become more desirable. For this reason a number of non-ablative treatments using different wavelengths were developed[15,16]. With ablative techniques, a reduction of superficial imperfections such as photodamaged skin can be achieved, but with non-ablative methods, a thermal effect produces a wound healing response and the stimulation of collagen remodeling, leading to tissue tightening. Non-ablative resurfacing aims to selectively heat dermal tissues, while sparing the epidermis from significant thermal injury thus reducing complications and recovery times.[17] This therapy relies on the selective heating of regions of tissue within the dermis, which is accomplished by using lower laser fluence rates or by protecting the epidermis using cryogen spray, contact, or air cooling. Diode lasers (532, 900 and 1450 nm), rare earth lasers such as Nd:YAG lasers and pulsed dye lasers (PDLs) have all been reported to improve skin appearance and textures[18,19].

3. Fractional Ablation

Fractional ablation, which is the most recent development in laser skin resurfacing, has existed conceptually for quite some time, though not implemented in practice. The term fractional photothermolysis was first coined by Manstein et al 23 in 2004. In fractional ablation, laser spots are small (approximately 100 µm) and are separated from one another by a considerable distance. Small regions of tissue injury (and hence remodeling) exist as islands surrounded by normal skin where reepithelialization is rapid [20]. The most popular fractional ablation devices operate at 1550 nm (Fraxel, Reliant Technologies, San Diego, California) [20,21]. Apart from being primarily used as a resurfacing tool, fractional photothermolysis has been used to treat pigmentation lesions, acne scars and surgical scars [22].

Complications and adverse effects are short-term and usually limited to erythema, skin dryness, and facial edema. Fractional photothermolysis is generally associated with a relatively high patient satisfaction rate, as high as 75% according to Cohen et al [23].

The main challenge for skin resurfacing in the future will be to achieve a long-term natural-looking substantial improvement in skin quality. Also, resurfacing and related technologies will strive toward achieving more dramatic results and postpone the need for traditional aging face procedures such as rhytidectomies and blepharoplasties.

A novel non-invasive method was introduced using the Er:YAG laser in a non-ablative SMOOTH mode for the treatment of mucosa tissue, which enabled the development of several new applications based on collagen remodeling and neo-collagenesis, such as laser vaginal tightening, stress urinary incontinence, treatment of snoring and apnea reduction . Recently one case study demonstrated promising results using a combination of intraoral and extraoral Er:YAG in SMOOTH mode for the reduction of nasolabial folds [24].

The latest promising results of Er:YAG use on mucosal tissue, combined with high patient interest for novel non-invasive methods for skin rejuvenation, prompted us to evaluate the efficacy and safety of intraoral treatment with the Er:YAG laser using the non-ablative SMOOTH mode for perioral wrinkle reduction.

B. Vascular Malformations & Hemangiomas

Facial erythema and telangiectasias remain some of the most common complaints of cosmetic patients. These lesions often develop in patients with rosacea or in those with a long history of photodamage and can be a common sign of the aging process. These lesions can be easily treated with laser technologies. In order to effectively treat these lesions, it is necessary to target the oxyhemoglobin within the vessels.

The key to treating vascular malformations and hemangiomas is selective destruction of the pathologic vasculature, while minimizing injury to surrounding normal tissues. A secondary challenge is protecting against absorption of light by epidermal melanin, which has an absorption profile similar to that of hemoglobin.

Multiple lasers can be used to target the chromophore oxyhemoglobin; however, the most commonly used laser for treatment of these lesions remains the PDL. It was initially developed to treat capillary malformations, port-wine stains in children. After PDL treatments, blood vessels were observed to contain agglutinated erythrocytes, fibrin and thrombi. One month after treatment, these damaged vessels were replaced by normal appearing vessels. Since its initial development, the use of PDL has been expanded to include facial telangiectasias, erythrotelangiectatic rosacea, facial rejuvenation and infantile hemangiomas. PDL has also been used to successfully treat many other skin conditions with increased vascularity including psoriasis, scars, verruca and skin malignancies such as basal cell carcinoma. The original PDL devices used short pulse durations (0.45–1.5 milliseconds), which are shorter than the thermal relaxation times of facial vessels. The best results for port-wine stain treatment are achieved using a PDL with cryogen cooling. Photodynamic therapy (PDT) and non-ablative therapies are effective against hereditary hemorrhagic telangiectasia [25].

C. Laser Assisted Hair Removal

In 1996, Grossman et al published the first report of laser hair removal by selective photothermolysis of hair follicles using a normal-mode ruby laser.As with other laser therapies, novel laser sources were soon introduced, including the Nd:YAG laser, the alexandrite laser and the diode laser. Although laser hair removal typically entails multiple treatments to achieve desired results, patient satisfaction for laser hair removal is generally high. Long-pulsed Nd:YAG laser showed greater proportion of hair reduction in hypertrichosis of the face, axillae and legs compared with intense pulsed non laser light source in darker skinned individuals[26]. The main disadvantage of laser hair removal is the requirement for a considerable melanin gradient between skin and hair follicles.

D. Laser Therapy Of Pigmented Structures

Q-switched laser systems, such as the 694 nm ruby-laser, the 532 nm and 1,064 nm Nd: YAG-laser, or the 755 nm alexandrite laser, are the gold standard for the treatment of benign pigmented lesions and tattoo removal. Indications for the q-switched ruby laser (QSRL) include, but are not restricted to, benign pigmented lesions (e.g. solar lentigo, ephelides, or certain nevi), tattoos (including dirt tattoos and permanent makeup), seborrhoeic keratosis, post-inflammatory hyperpigmentation, melasma, or drug-induced dyschromias.

The treatment of pigmented lesions using q-switched laser systems generates extreme energy and heat peaks that vaporise the water of the tissue surrounding the pigments. This vaporisation, and the photodisruption of the pigment, results in a 'snapping' noise and a whitish discolouration of the skin, i.e. the so-called blanching phenomenon. The blanching correlates with the generation of gas bubbles within the dermis and usually vanishes over a time period of 10-20 minutes.

1. Laser Therapy of Tattoos

The type of tattoo has an immediate influence on the efficacy of the laser tattoo-removal. Additional factors that influence the selection of the ideal type of laser and the efficacy of the treatment include colour, location, age, and skin-type of the patient. Whereas amateur tattoos often can be removed within 3-6 sessions, professional tattoos may require >20 sessions; the 694 nm ruby-laser may effectively remove black, dark blue, or green colours, while red colours can only be removed effectively with 532 nm Nd:YAG lasers. Multi-colour tattoos require the combination of different laser systems.

It is recommended to start the therapy using defensive parameters in order to avoid complications in the course. Therapy is performed using superficial analgesia with cooled air.Topical anaesthetics can be applied prior to therapy in sensitive patients.. Topical sun screen (SPF 50+) is advised throughout the entire treatment period. Treatments are repeated every 4-6 weeks.

The use of the QSRL(Q-switched ruby-laser) can achieve excellent cosmetic results nevertheless, the patient must be educated prior to the therapy that the tattooing-process often results in a permanent alteration of the skin-structure. Hence, removing the colour from the tattooed area may 'uncover' a tattoo-shaped scar . If the patient is not educated about this fact, the individual may associate the scar with the process of an 'incorrect' laser-therapy. Furthermore, in approximately 40% of the cases, QSRL-therapy is associated with transient hypo-pigmentation [27] This may be permanent in approximately 10% of the cases. The occurrence of hypopigmentation correlates with the number of treatment-sessions. Another potential complication must be warranted when treating cosmetic tattoos. In fact, laser therapy of red permanent makeup, which is usually applied to accentuate the contour of lips, may result in an oxidation of the pigment and a subsequent black discolouration. Hence, when treating permanent makeup, a test-treatment is mandatory.

Anderson and Parrish[1] recently published the so-called 'R20' method.[28]. The authors propose that the blanching that is observed after the treatment of tattoos using q-switched laser systems limits the number of effective passes to one, as the forming gas bubbles in the dermis scatter light and prevent the laser from reaching pigments located in the deeper dermis. However, the application of multiple passes after the blanching vanished (approximately 20 minutes, and therefore, 'R20'-technique) in one session resulted in a significant increase of the efficacy of each session and able to reduce the number of sessions by approximately 25% when performed two passes per session.Thus, q-switched laser systems that emit extreme short pulses in the picosecond range have been proposed to effectively remove multi-coloured tattoos within one or two sessions.[29,30].

2. Laser Therapy Of Benign Pigment Lesions

The QSRL is extremely effective in the treatment of benign pigment lesions. In particular when treating facial pigmented lesions, the differential diagnosis includes lentigo or even lentigo maligna melanoma. Therefore, it is advised to perform histopathological analysis of shave biopsies prior to any laser-treatments of facial pigmented lesions, if possible, or at least if there are any signs of atypia. Facial pigmented lesions that reoccur after laser-therapy should undergo immediate histopathological evaluation.

IV. Conclusion

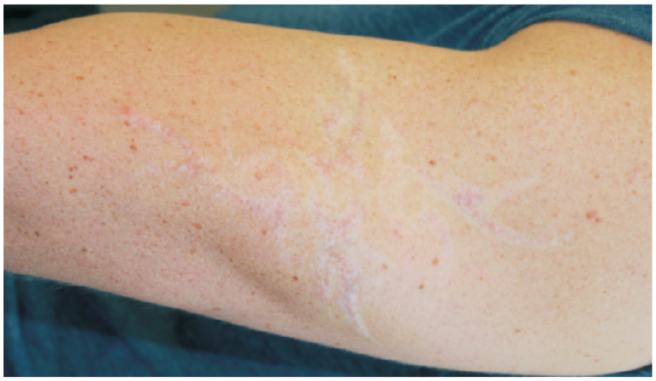
Lasers have revolutionized the field of facial aesthetics. The clinician should understand the basics of laser science, tissue effects of lasers, various laser wavelengths and parameters. It is important on the clinician's part to take full advantage of the features of lasers and provide safe and effective treatment to the patient. While they currently have significant roles in rejuvenation, hair removal, and fat ablation, lasers and optical technologies are becoming increasingly important for noninvasive imaging and targeted individualized therapy. Treatment of complex lesions such as port-wine stains will become more sophisticated as high-resolution imaging modalities and the wound healing response are studied more extensively. Novel techniques and laser-systems grant interesting and novel treatment options for new and experienced users. The growing interest in therapies that take individualized maximum safe radiant exposure into consideration will increase the treatments' individuality, safety, accuracy and ease.

Pictures

Skin rejuvenation

Laser hair removal

Treatment of a professional tattoo using the q-switched ruby laser.



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