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ScienceDirect
Medical Laser Application 23 (2008) 93–98
Medical Laser Application
www.elsevier.de/mla

Ablative fractional photothermolysis – A novel step in skin resurfacing

Tobias Goerge, Nadine Peukert, Hans Bayer, Anita Rütter*

Department of Dermatology, University Hospital Münster, Von Esmarch Strasse 58, 48149 Münster, Germany

Received 28 January 2008; accepted 4 February 2008

Abstract

Non-ablative fractional photothermolysis (nFP) produces specific thermal injury areas called microthermal treatment zones (MTZ) at specific depths in the skin. The surrounding tissue of the MTZ and the stratum corneum of the epidermis remain intact during treatment, leading to rapid healing of the injured tissue. Macroscopic wounding is not apparent. Mild to moderate erythema and edema are usually apparent for several days post-treatment, therefore there is only minimal downtime for the patient. Several treatment courses are required, as it is known from other non-ablative laser procedures. Recently a novel prototype ablative CO_2 laser device operating in a fractional mode (ablative fractional photothermolysis, aFP) has been developed, presenting a new and promising laser technology in skin resurfacing.

Keywords: Fractional photothermolysis; Fractional resurfacing; Infrared laser; MTZ

Introduction

Resurfacing of photodamaged facial skin with ablative laser modalities represents a well-known and standardized treatment from the rejuvenation procedures available. Various controlled studies have clearly demonstrated the clinical efficacy of these techniques using infrared lasers such as CO_2 (10,600 nm) or the erbium: yttrium–aluminum–garnet (Er:YAG, 2940 nm) [1–3]. Both CO_2 and Er:YAG lasers target water as a chromophore and are frequently used for skin tightening and resurfacing [4]. In practice, ablative laser treatments still have inconvenient limitations due to the significant downtime for the patient and a variety of side effects [5].

Non-ablative laser devices, such as neodymium: YAG (Nd:YAG, 1064 and 1320 nm) commonly use the principles of selective photothermolysis (SP), targeting hemoglobin as a chromophore, and emitting coherent light at wavelengths absorbed by water.

These lasers induce thermal injury of the dermal tissue containing blood vessels. Due to the absence of vascularization in the epidermis, the superficial tissue layers remain unaffected [6]. As these lasers also target melanin as a chromophore, superficial skin cooling is required in order to avoid thermal damage in the epidermis [5,7]. The choice between a more invasive, ablative laser device and a possibly less effective non-invasive, non-ablative laser modality for skin resurfacing has been a bit of a dilemma. However during the last few years there has been increasing interest in less invasive but more effective laser treatment methods particularly for photo-aged skins.

A promising advancement in non-ablative laser therapy, known as fractional photothermolysis (FP), has recently been introduced [7]. This novel non-ablative resurfacing laser modality creates minimal thermal

*Corresponding author. Tel.: +49 2518 356517; fax: +49 2518 358579.
E-mail address: anita.ruetter@ukmuenster.de (A. Rütter).

1615-1615/$ - see front matter © 2008 Elsevier GmbH. All rights reserved.
doi:10.1016/j.mla.2008.02.002

injuries in the epidermis and dermis known as micro-thermal treatment zones (MTZ). For this a mid-infrared laser, emitting at 1500 nm, is used. By sparing the surrounding tissue, re-epithelization proceeds from viable cells in the epidermis and dermis within 24 h, thus significantly reducing the downtime for the patient. Further engineering of non-ablative FP has led to the novel concept of ablative fractional resurfacing. This involves replacing the mid-infrared laser modality with a 10,600 nm CO_2 laser source, and the microcolumn of epidermal and dermal tissues is not only coagulated but also removed [7].

Rejuvenation procedures

Ablative skin resurfacing

The classical resurfacing treatment is based on either CO_2– or Er:YAG laser. Targeting intracellular water, ablative CO_2 lasers emit light in the infrared spectrum at 10,600 nm, capable of heating cells to more than 100 °C. The results are vaporization and ablation of the epidermis and well-defined superficial layers of the dermis. Coagulation necrosis of cells and denaturation of extracellular proteins in residual layers of the dermis are evident upon microscopic analysis. Due to heat-induced collagen shrinking, an immediate skin tightening-effect is followed by remodeling and deposition of both extracellular matrix fibers and ground substance during the subsequent healing process. In general, the clinical outcome is a smoother and tighter skin although varying results of the clinical efficacy have been reported [1,8].

The 2940 nm Er:YAG laser also targets intracellular water. Er:YAG laser ablation is more superficial and is considered less ablative than the CO_2 laser. Compared with the CO_2 laser, the Er:YAG laser results in less dermal collagen remodeling. Its clinical application is used above all in the treatment of mild solar elastosis and moderate rhytides. In general, the clinical efficacy increases with the depth of thermal injury [9].

Both CO_2 and Er:YAG lasers represent well-accepted procedures for facial resurfacing, reliably improving the appearance of photo-induced wrinkles and dyschromia [10]. Er:YAG lasers often show accelerated healing compared with CO_2 lasers due to their more superficial absorption depth. However, they produce less efficient coagulation and thus more bleeding. To resolve these limitations, sometimes both laser systems are used in combination with one another to improve clinical effects and reduce adverse events [7,11].

Complete epidermal ablation using these laser technologies may lead to a failure of the skin barrier function and, as a consequence, to a prolonged post-treatment recovery phase. Unwanted side effects, such as erythema and edema, pigmentary alterations (hypo- and hyperpigmentation), infection, milia formation, scarring and, in rare cases, fibrosis may occur. Erythema can unfortunately persist for 3 months or even longer. In general, patients have to expect prolonged downtime post-treatment. Furthermore, there is a high risk of scarring, when treatment is performed in non-facial areas, such as the neck and décolleté due to the relatively small number of pilosebaceous glands in these areas [12,13].

Non-ablative laser technologies for skin rejuvenation

Non-ablative laser skin rejuvenation is a non-invasive approach to tissue remodeling. The clinical spectrum for non-ablative lasers is the mild to moderate photodamaged skin [14]. Non-ablative laser devices, such as neodymium:YAG (Nd:YAG, Q-switched, long-pulsed, 1064/532 nm, and long-pulsed 1320 nm), dye laser (pulsed, 585/595 nm) commonly use the principles of SP, targeting hemoglobin as a chromophore. Other frequently used non-ablative devices for skin rejuvenation are the 1540 nm erbium glass laser and the 1450 nm diode laser or intense pulsed light sources (IPL technology, 500–1200 nm) [14–16]. As could be demonstrated in studies, remodeling of collagen was evident upon histological examination and clinical improvement of wrinkles was achieved. However, there is a high variety regarding the clinical outcome of these procedures, and it may take considerable time before observing positive clinical achievements. In addition, severe clinical signs of photodamaged skin, such as dyschromia or poikiloderma appear not to be adequately addressed using non-ablative laser modalities [17,18].

Non-ablative laser modalities do not disrupt the skin barrier function and therefore exhibit a high level of clinical safety and reduced adverse events when compared with ablative laser treatment procedures. The clinical results vary according to the lasers and the light sources used, and the laser surgeon using them. However, these technologies often suffer from a low or inconsistent clinical efficacy. A highly acclaimed and major advantage of non-ablative skin rejuvenation is the lack of any downtime for the patient post-treatment [19,20].

So far, non-ablative photorejuvenation is not a single treatment technique but is comprised of a number of different methods. The aim of the treatment is to improve epidermal pigmentary alterations, vascular abnormalities, or structural damage in the dermis, modulating the extracellular matrix components such as elastic fibers and collagen. The migration and proliferation of fibroblasts is stimulated. The clinical spectrum for the use of non-ablative lasers are the signs of mild to moderate photodamaged skin [17,21]. In theory, these laser modalities selectively damage dermal