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How to perform ablative laser surgery for skin resurfacing?

Deri yüzey yenileme için ablatif lazer cerrahisi nasıl uygulanır?

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Introduction

The word laser is an acronym for "light amplification by stimulated emission of radiation." Throughout the past half-century, the better understanding of cutaneous physiology and laser technology has substantially improved to provide a sophisticated perspective for laser-skin interactions. Basic knowledge of the fundamentals of laser physics is essential to understanding laser devices[1]. Ablative lasers lead to the controlled removal of the outer layer of the skin along with various degrees of heat formation within the dermis. Ablative lasers have proven efficacy for skin rejuvenation hence commonly used in aesthetic dermatology. Additionally, they are increasingly implemented into medical dermatology for various skin disorders' management[2]. This study aimed to reveal the basic information in using ablative lasers and illustrate the numerous indications based on the physician's creative potential.

The theory of "selective photo-thermolysis" of Anderson and Parish in 1983 is a mile-stone for laser physics. According to this theory, thermal damage can be confined to a selected target within the exposed tissue. This target is determined by laser device wavelength and may include hemoglobin, melanin, exogenous pigment, or water. The target chromophore of ablative lasers is water. Three criteria must be fulfilled to sustain a pure ablation effect during laser applications and eliminate heat generation within the tissue. First, the target chromophore (water) must more avidly absorb the given wavelength than the surrounding tissue. Second, the duration of laser exposure (pulse duration) must be less than the thermal relaxation time of the exposed tissue. Third, laser procedures must be applied with sufficient high-energy settings to yield ablation[3].

The ablative lasers in dermatologic practice include carbon dioxide (CO_2) and Erbium:yttrium-aluminum-garnet (Er:YAG) lasers, which emit light in the infrared spectrum. The exposed tissue rapidly heats due to the preferential absorption of energy by intracellular water, which leads to vaporization. The wavelength of the Er:YAG laser (2940 nm) is closer to the absorption peak of water (3000 nm) compared to that of the CO_2 laser (10,600 nm). Consequently, during Er:YAG laser applications, almost all energy is absorbed in the epidermis and papillary dermis, yielding superficial ablation with less accompanying thermal tissue damage and thermo-coagulation[4]. Contrarily, heat generation and coagulation are prominent features of CO_2 laser applications. Extreme heat generation is avoided during ablative laser surgeries to diminish ominous long-term complications, such as post-inflammatory hyperpigmentation and scarring. However, heat generation can be beneficial and/or are required for certain conditions since the thermal effect stimulates collagen production and provides hemostasis. Conventional Er:YAG lasers lead to almost pure ablation with minimal thermal damage; however, coagulation can be acquired to a certain degree by novel devices by increasing pulse duration. Even by adjusting laser parameters, Er:YAG lasers are

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considered gentler and cooler than CO_2 lasers. For example, bleeding is troublesome during hidradenitis suppurativa (HS) surgeries, and CO_2 lasers provide a clean surgical field and are commonly implemented in the surgical management of HS (Figure 1). Even with maximal pulse duration settings, Er:YAG laser surgery is not a viable approach for these procedures. The laser surgeon should determine the suitable device and appropriate laser settings, including energy and pulse duration, according to his/her experience and purpose of the intervention.

The authors re-purpose delicate target tissue removal for various cutaneous disorders.

Examples include the following:

- Removal of precancerous epidermal cells may decrease augmented skin cancer development in high-risk patients. Patients with field cancerization and/or genetic syndromes characterized by an increased susceptibility to skin cancer development, such as xeroderma pigmentosum, are eligible for this approach (Figure 2).
- Removal of skin disorders that are characterized by mosaicism, such as epidermal nevi or Hailey-Hailey disease, stands as another medical indication. After removing these lesions, the wild-type clone has been hypothesized to have a survival advantage over the mutant type, leading to the complete healing of these lesions (Figure 3)[5].
- Chronic cutaneous infections are characterized by impaired resolution related to either pathogenic agents or patient-related factors. These infections are frequently resistant to topical agents due to their anatomic localization and/or biofilm formation. The removal of these lesions with laser ablation has a curative potential and makes the intervention site eligible for further topical antibiotic penetration (Figure 4).

Figure 1. A) Hidradenitis suppurativa. The treatment area is marked before the intervention. Note the red aiming beam of visible light guiding the CO2 laser beam. B) The marked margins are ablated, the lesional HS skin is removed, and the lesional skin base is regionally ablated to remove the underlying affected skin. The pronounced coagulation provides a bloodless area throughout the procedure. C) Complete epithelialization was achieved on the second month of the intervention

CO_2: Carbon dioxide

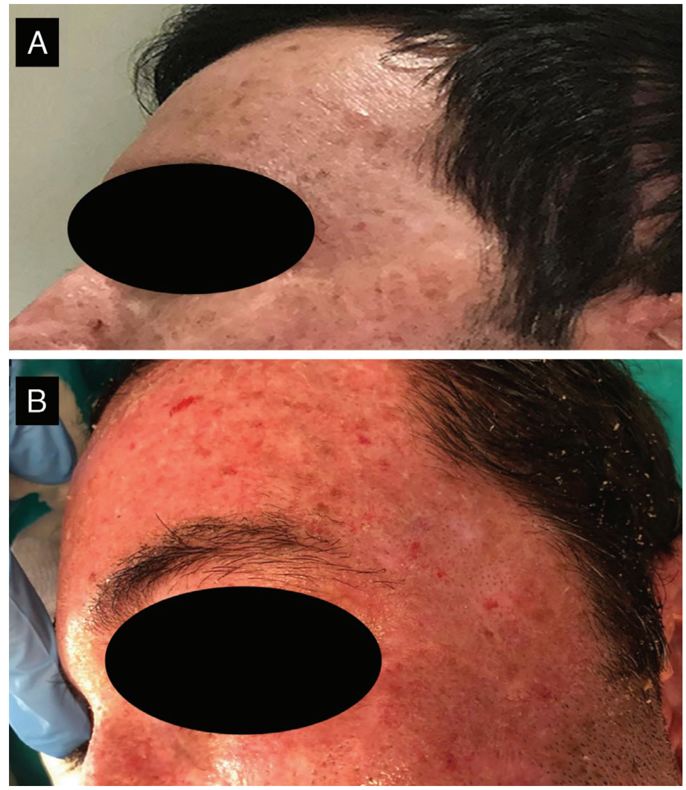

Figure 2. A) Xeroderma pigmentosum. A 34-year-old patient with an enormous number of skin cancers had undergone innumerable surgical procedures. The patient was introduced with annual full-field Er:YAG laser to decrease skin cancer development. B) The level of ablation was papillary dermis and pin-point bleeding was the indicator for acquiring this level

Er:YAG: Erbium:yttrium-aluminum-garnet

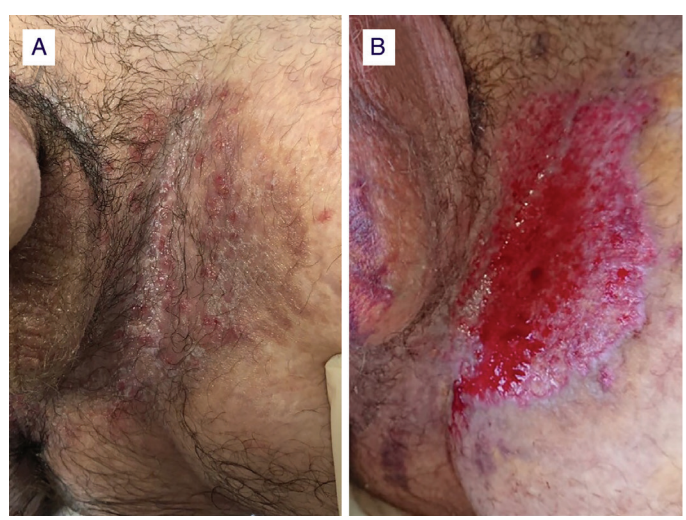

Figure 3. A) Hailey-Hailey disease. The patient had extensive bilateral inguinal region involvement. B) Left inguinal skin was ablated with full-field Er:YAG laser. Note the prominent bleeding with minimal coagulation

Er:YAG: Erbium:yttrium-aluminum-garnet

- Level-controlled debridement can be used to simulate almost all chronic ulcers (Figure 5). This precise removal technique can even be implemented to extraordinary indications like pyoderma gangrenosum and middle-sized vessel vasculitis-related ulcerations along with immunosuppression[6]. The stimulation of granulation tissue formation, photo-microdebridement, the resolution of adjacent skin sclerosis, are the additional benefits of ablative laser interventions of chronic wounds[7]. During the initial stages, wound edges can be treated. After removing the fibrinoid tissue as the healing progresses, the wound bed treatment would be suitable for ablative fractional laser (AFL) sessions.
- Hamartomatous skin lesion removal is frequently applied by ablative laser treatment. However, recurrence is a major drawback of the intervention. Hence, ablative laser applications have been replaced by novel targeted treatments in various genodermatoses, which are well-known for tuberosclerosis. Currently, rather than performing aggressive ablative laser interventions, tuberosclerosis-related hamartomatous lesions are treated with topical sirolimus cream. However, both modalities can be combined to achieve optimal results, especially for large lesions that tend to be recalcitrant or characterized by a slow response (Figure 6).
- Cutaneous deposits (e.g., lichen amyloidosis and xanthelasma) removal can be successfully acquired by laser ablation (Figure 7).

Ablative laser surgeries are classified into two main groups according to ablation patterns as full-field and fractional applications. The oldest devices enabled only continuous full-field ablation; in advance, the developments included pulsed full-field applications and, more recently, fractional ablation. For a long period, full-field CO_2 laser was regarded as the gold standard in skin resurfacing. However, the frequent side effects, including dyspigmentation and extended procedure-related downtime, limited this approach's utilization. The concept of fractional photothermolysis was introduced in 2004, which enabled the selective limited removal of epidermal and dermal microcolumns without the impairment of the overall tissue architecture. Thus, the preserved skin allows a more rapid epithelialization with a less significant side effect profile than full-field resurfacing[8]. In addition to their indications, the preoperative and postoperative instructions differ for these two approaches; hence, the authors will discuss them under two headings, respectively.

Ablative full-field laser applications

Fractional counterparts have largely replaced full-field applications; however, ablative full-field laser surgeries are still predominantly performed for medical purposes (Table 1). Full-field laser applications are painful hence require anesthesia. CO_2 laser applications are more painful than Er:YAG laser applications since the thermal effect within the dermis stimulates C fibers. Especially localized and superficial procedures of Er:YAG laser may be performed with topical lidocaine cream or infiltration anesthesia. Additionally, extensive procedures should be performed by nerve blocks or under systemic sedoanalgesia.

Figure 5. A) Diabetic foot ulceration. B) The devitalized component was removed by full-field Er:YAG laser. The pulse duration was kept to a minimum to observe bleeding through the vitalized tissue level

Er:YAG: Erbium:yttrium-aluminum-garnet

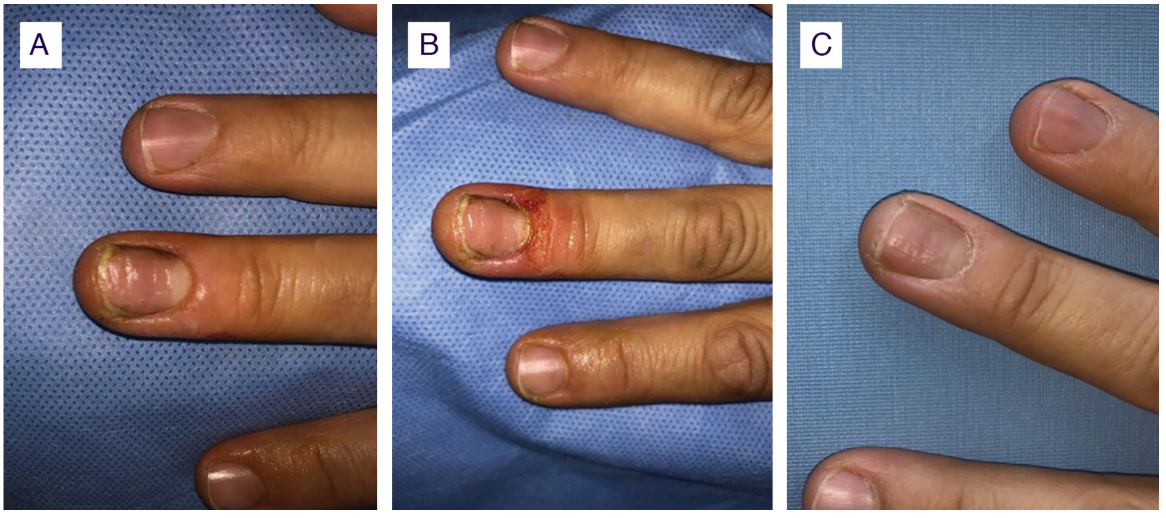

Figure 4. A) Chronic paronychia. The patient had been prescribed several oral and topical antifungal agents without a treatment response. B) The lesional skin was ablated with full-field Er:YAG laser and only topical petrolatum ointment were used as a wound dressing. C) The resolution of chronic paronychia was detected on second month control

Er:YAG: Erbium:yttrium-aluminum-garnet

Figure 6. A) A 21-year-old patient with tuberosclerosis requested rapid facial lesion healing. A fractional CO_2 laser was introduced as an adjuvant to topical sirolimus cream. B) Immediately after the laser intervention, the same level was acquired with the surrounding skin

CO_2: Carbon dioxide

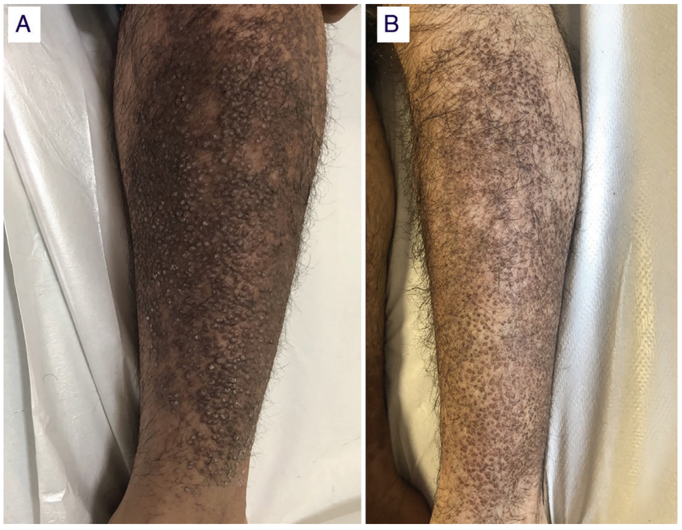

Figure 7. A) Lichen amyloidosis. The patient with a long-standing disease course received fractional Er:YAG laser that is immediately continued with topical clobetasol propionate ointment. Full-field ablative laser applications are more suitable for accumulative conditions; however, AFL treatments can be preferred in extensive involvement with improved patient compliance. A dramatical regression was obtained for the represented patient both in terms of pruritus and existing lesion infiltration. B) Clinical image on 6 weeks follow-up

Er:YAG: Erbium:yttrium-aluminum-garnet, AFL: Ablative fractional laser

An alternative approach is topical lidocaine/prilocaine application before ablative laser resurfacing and laser treatment introduction with low-dose settings. The superficially ablated skin is more eligible for enhanced topical agent penetration. Topical lidocaine/prilocaine can be applied several times throughout the procedure, and energy settings can be steadily increased. However, patient comfort was severely disturbed, especially for extensive applications, thus this approach should be reserved for limited indications[2].

Careful preoperative consideration is imperative for optimal outcomes, including the evaluation of patient expectations and skin phototype. A thorough medical history should be taken. Patients with a history of keloids should not undergo ablative full-field laser resurfacing as an aggressive procedure may lead to new lesion formation. Isotretinoin treatment also stands as a contraindication for ablative full-field laser applications due to the increased risk of excessive scarring[9]. The eligible time for ablative laser resurfacing should extend to a year after isotretinoin cessation[10].

Additionally, cutaneous disorders that are characterized by reduced adnexal structures, such as radiodermatitis and scleroderma, are considered contraindications. This statement is related to impaired postoperative epithelialization due to the relative absence of the epidermal stem cells. Patients with dermatologic disorders that are characterized by the Koebner phenomenon, e.g., vitiligo and psoriasis, should be cautioned about the risk of exacerbation, which are considered relative contraindications.

Valacyclovir should be prescribed, especially for patients who experience recurrent herpes episodes. The requirement for prophylactic antibiotics is controversial and mainly depends on the instructor's experience. Through their practice, the authors administer prophylactic cefazolin treatment immediately before the procedure and continue oral antibiotics for a week in every extensive procedure that requires sedoanalgesia. The antibiotics of choice usually include cephalosporins, penicillins, or macrolides. Some laser surgeons prescribe antifungals, such as fluconazole, to prevent secondary fungal infections, although it is uncommon. Preoperative topical retinoids may be recommended since they are thought to enhance wound healing after ablation[10]. Additionally, some practitioners prescribe prophylactic systemic corticosteroids for a few days to prevent edema.

The treatment area should be thoroughly cleaned before the procedure. Alcohol is generally not recommended for skin preparation because it might lead to an explosion as a volatile. Appropriate eye protection is crucial. Patients must wear steel eye shields and all operating personnel must wear protective eyeglasses to prevent accidental exposure at all times when the laser system is switched on. The door of the treatment room should be kept closed throughout the procedure.

Table 1. Implicated indications of full-field ablative laser resurfacing in medical dermatology
- Restoration of the cutaneous tissue
- Removal of localized skin neoplasia and/or hamartomatous lesions
- Removal of the cutaneous deposits
- Removal of lesional skin in hidradenitis suppurativa Hailey-Hailey disease
- Level-controlled debridement in cutaneous ulcers

All the controls of the laser systems are located on the front panel. The laser surgeon adjusts the spot size according to the treatment area. The determined spot size that is depicted on the laser device screen should match the handpiece's spot size. A low-power visible red aiming beam is implemented as a guide for the laser emission. The integrity of the laser beam should be checked by this guide. After the appropriate parameter selection, the footswitch is pressed to initiate treatment. The laser plume may contain viable ablated tissue particles; hence, the use of a smoke evacuator during treatment, especially during extensive applications, is highly recommended. The treatment duration depends on the total treatment area. In addition to a single pass, multiple passes can be performed to provide delicate level-controlled ablation. Immediate target tissue removal occurs during full-field ablative laser surgeries. The tissue can be wiped off with wet gauzes between the consecutive laser passes. Er:YAG laser applications enable better ablation depth visualization due to the absence of coagulation. The demanded level of ablation is generally confined to the papillary dermis for aesthetic procedures and scarring, which reveal pin-point bleeding. Additionally, during the treatment of hamartomatous or neoplastic skin lesions or cutaneous deposits, the treatment should be continued till the acquisition of the same level with the surrounding skin. The possibility of contact sensitization is augmented due to the impaired epidermal barrier, and topical antibiotics should be avoided to prevent allergic contact dermatitis. Pure petrolatum ointment or bio-occlusive dressings are preferred for wound care at the end of the procedure, and closed dressings should be continued until complete epithelialization is accomplished. The laser handpiece must be cleaned with alcohol to remove the remaining particles.

In the postoperative period, edema and exudate formation are common findings along with desquamation. Ice-cold soaks may assist in acute pain and inflammation control. Systemic corticosteroids may be prescribed over a short term (2-3 days) in case of severe edema. Wet compresses are helpful for exudate and pain diminution. Sun exposure must be minimized both before and after the laser interventions since sun exposure might lead to dyspigmentation. The duration of complete epithelialization depends on the treated zone size and may extend to 2-3 weeks. During the first 2 postoperative weeks, patients should be warned about alarming symptoms, such as pain, purulent drainage, and itching. These alarming symptoms warn the clinicians to perform bacterial cultures.

AFL applications

The established indications of AFL include cutaneous scar remodeling and rejuvenation. Furthermore, AFL enhanced topical agent delivery through thermal microcolumns is a focus of attention and is increasingly implemented in the medical management of various skin disorders[11].

Administering both ablative full-field and fractional ablative applications with the same laser device is possible by changing the handpiece. The handpiece attached to the articulated arm should match with the handpiece type selected on the control panel. Generally, the preoperative considerations for full-field ablative resurfacing exist for AFL applications; however, they are more flexible. For example, all skin phototypes are suitable for the procedure. In high-risk patients, density and energy settings should be adjusted to prevent dyspigmentation. Additionally, contrary to full-field resurfacing, the patients receiving isotretinoin can undergo AFL.

Antiviral drugs are generally prescribed for AFL procedures, but in localized procedures, this preference depends on the laser surgeon's experience and treatment region. Prophylactic antibiotics should only be considered in aggressive interventions. Cold-air cooling may be used to optimize patient comfort. Topical anesthetic agents that are applied 60 min before the procedure are generally sufficient for pain control. AFL sessions are physician and device-dependent. Erythema, edema, and mild oozing are common and generally mild. Crusting may be encountered after aggressive applications.

The delicate observation of ablation depth is impossible during AFL as pin-point bleeding does not occur due to the preserved skin regions and the gross effect of the intervention is erythema. Thus, the laser surgeon should depend on the available literature data based on the histopathological evaluation of AFL-exposed skin to select appropriate treatment parameters.

Ice-cold soaks and wet dressings may be applied in the postoperative period. Closed bandages are commonly not required after AFL. Like their full-field counterparts, sun avoidance and protection are central to eliminating treatment-related complications after AFL.

Ablative lasers have proven efficacy, and the risks and complications of the interventions can be minimized by strict preoperative and postoperative recommendation concordance. In addition to aesthetic purposes, full-field and fractional ablative laser applications can be repurposed according to the clinician's perspective for medical indications.

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