REVIEW
Fractional FRAC3® and Twinlight™ Laser Skin Treatments

Tomaz Bevec,[1] Matjaz Lukac[2]
[1]*Fotona d.d., Stegne 7, Ljubljana, Slovenia*
[2]*Jozef Stefan Institute, Light and Matter Department, Jamova cesta 39, Ljubljana, Slovenia*

ABSTRACT

The results of published studies on two of the latest laser skin rejuvenation methods, *FRAC3*® and Twinlight™, are reviewed.

The non-ablative *FRAC3*® Nd:YAG laser method creates a self-induced 3-D fractional effect which is localized at areas of pre-existing skin damage. *FRAC3*® differs intrinsically from other fractional technologies in which the beam itself is fractionated upon delivery. By contrast a *FRAC3*® beam is whole upon contact with the skin surface and is thereupon fractionated by skin imperfections as it proceeds towards the subcutaneous tissue.

The Twinlight™ skin resurfacing treatment combines two complementary fractional laser procedures into a single, synergistic treatment. In the first step, the skin is subjected to the Nd:YAG laser *FRAC3*® photo-thermal therapy. In the second step, a fractional Er:YAG treatment is performed.

The new *FRAC3*® and Twinlight® laser methods are the next step in improved laser skin treatment procedures, with good efficacy and selectivity coupled with short healing time.

Key words: laser skin rejuvenation, fractional, Frac3, Nd:YAG laser, Er:YAG laser, laser skin resurfacing, Twinlight

Article: J LAHA, Vol. 2011, No.1; pp. 43-48.
Received: March 11, 2011. Accepted: March 25, 2011.

I. INTRODUCTION

Various laser treatment modalities have become standard in cosmetic and non-cosmetic skin rejuvenation. Broadly, these modalities can be split into two basic categories: ablative and non-ablative. Non-ablative modalities emphasize patient comfort and a low or no downtime approach to treatment; in exchange they do not produce the dramatic results of ablative treatments, such as Er:YAG resurfacing. Recently both researchers and practitioners have begun to show an increased interest in non-ablative treatments which suggest that these treatments are becoming more prevalent. Fractional ablative techniques are also gaining popularity because they are associated with shortened recovery periods [1]. Fractional techniques are based on the production of an array of discrete microspots within the skin, allowing the unaffected sub-areas in the skin to act as healing centers.

Standard approaches to fractional treatment make use of fractional illumination in the form of a two dimensional matrix; the illuminated columns below the laser spots are damaged uniformly. Recently, a novel *FRAC3*® non-ablative fractional laser method [2] was introduced that produces a self-induced fractional thermal damage matrix within the skin tissues. [3-6] The method utilizes the fractional nature of the selective photo-thermolysis at short Nd:YAG laser (1064 nm) pulse durations. [7] With *FRAC3*®, the resulting fractional damage islands are not limited to the two-dimensional column matrix but are distributed in a three-dimensional manner throughout the skin volume.

FRAC3® skin rejuvenation has been shown to improve atrophic scarring, texture, wrinkles and PIH in patients, even in dark skinned patients [8-11]. The Nd:YAG laser used in *FRAC3*® treatment stimulates new collagen synthesis, as demonstrated by histology [12]. However, because of its non-invasiveness *FRAC3*® does not lead to results as dramatic as, for example, full face Er:YAG laser (2940 nm) resurfacing. When more pronounced results are desired or required investigators have started using a Twinlight™ method that combines non-ablative *FRAC3*® rejuvenation with ablative fractional Er:YAG techniques . [13-16]

The new *FRAC3*® and Twinlight™ laser methods are the next step in improved laser skin treatment procedures, given their efficacy, selectivity, short healing time and cost effectiveness. Recent studies have demonstrated the safety and efficacy of *FRAC3*® and Twinlight® treatments and have proposed protocols suitable for both dark and light phototypes. Those protocols, along with a number of other theoretical and practical considerations are discussed in this paper.

II. METHODS

a) *FRAC3®* rejuvenation

All non-ablative skin rejuvenation modalities are based on the damage of deep layers of skin but the sparing of superficial layers [9]. If the clinical objective is to cause selective modifications of a specific tissue structure, the laser wavelength should match the highest absorption of the targeted structure relative to the surrounding tissue. However, wavelengths that are highly absorbed in skin imperfections are typically also highly absorbed by non-target structures, e.g. melanosomes [4] or hemoglobin-containing RBCs [3]. These wavelengths consequently do not reach deeper-lying skin imperfections or hair follicles, which can result in excessive damage to healthy skin structures. For this reason, it is often better to select a laser wavelength that penetrates deeper into the tissue, and then achieve selective tissue modification by adjusting the laser pulse duration to the thermal relaxation time of the targeted imperfection. During a lengthy laser exposure most of the deposited heat will diffuse away from the skin target structure, resulting in nonspecific thermal damage to adjacent structures. Conversely, a suitably short laser pulse minimizes the time available for heat diffusion and confines the heating effect to the target structure, resulting in maximum temperature difference between the target and adjacent structures [6]. Using a homogeneously penetrating Nd:YAG (□ =1064 nm) laser wavelength, [5-6] and targeting skin imperfections by adjusting the laser pulse duration to the cooling times of these imperfections is the paradigm behind the *FRAC3®* minimally invasive skin rejuvenation technique (See Fig. 1).

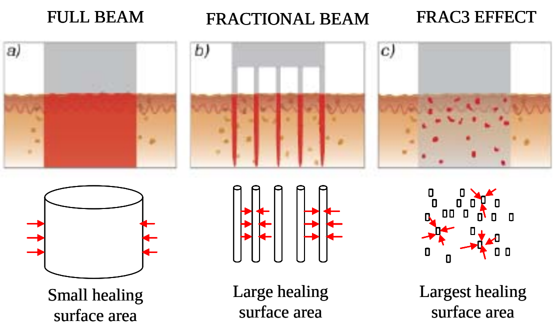

Fig. 1: Laser induced damage islands as healing centers: a) standard uniform laser treatment; b) standard two-dimensional fractional treatment; and c) novel self-induced three-dimensional FRAC3 laser treatment. With the FRAC3 method the tissue is treated only where required, i.e. at skin imperfections. In addition, with the FRAC3 the healing area is the largest, and the healing time is the fastest.

When light at *FRAC3®* parameters is applied to skin it auto-fractionates in response to interactions with imperfections or non-homogeneities, thereby selectively heating areas of damage. *FRAC3®* differs intrinsically from other fractional technologies in which the beam itself is fractionated upon delivery. By contrast a *FRAC3®* beam is whole upon contact with the skin surface and is thereupon fractionated by skin imperfections as it proceeds towards the subcutaneous tissue.

The emergence of isolated "fractional" thermal islands within the skin have been demonstrated with in-vivo thermal measurements of the skin surface and in-vitro measurements of skin cross-sections following illumination with sub-millisecond Nd:YAG pulses. Roughly, *FRAC3®* treatments are performed with laser pulses of 0.1-5 ms width and with fluences of 10-70 J/cm2. When applied specifically to skin resurfacing sub-millisecond parameters from 0.1-0.4 ms are used together with fluences in the range of 10-40 ms; when applied to hair removal parameters at the higher end of the scale are standard [6].

Laser physics dictate that the effective fluence of a laser beam is reduced as the spotsize of the laser beam is decreased because the scattering radius stays constant as the laser beam decreases and therefore more light is scattered. Due to scattering the greatest photo thermal effects for Nd:YAG light are seen 1 to 2 mm below the surface of the skin [9]. A *FRAC3®* beam penetrates to the lower end of that range because, given the limitations inherent in modern commercial medical laser systems, relatively small spotsizes are a necessity if *FRAC3®* parameters are to be achieved. Despite this an approximately 1 mm penetration depth means that a *FRAC3®* beam can treat imperfections throughout most of the dermis.

FRAC3® is a submillisecond modality because shorter pulsewidths are needed to heat small imperfections. Submillisecond pulses can therefore heat structures which are in the neighborhood of a 100 um in diameter [6]. There are indications that *FRAC3®* pulses might even provide the thermal selectivity to treat the microvascular components which cause erythema [10]. Theoretical calculations indicate that the temperature rise in the epidermis is twice the rise in the papillary dermis and 5 times the temperature rise in the dermis.

Dermal remodelling can be induced by heating the skin to 55°C [17]. The amount of damage caused to the skin by temperature is dependent upon time (one classic study found that,at 50°C a 9 minute exposure caused permanent and irreversible damage, while at 7 minutes there was no injury [18]). However, *FRAC3®* parameters are far away from these boundaries. Nevertheless, *FRAC3®* does cause bulk heating along with the specific fractionated heating of imperfections [5].

Based on the considerations above, it is probable that *FRAC3®* skin rejuvenation treatments act through two orthogonal mechanisims: specific damage to imperfections caused by direct absorption in those imperfections (comprised often of damaged, dense cells) and bulk heating of the skin [8].

One feature of the *FRAC3®* treatment method is its requirement for relatively high fluences at short pulse durations, which is difficult to achieve with larger spot sizes. *FRAC3®* treatments are therefore typically performed with a small beam spot size. Yet manually aiming a small to medium spot size laser beam hundreds of times to cover a larger skin area can lead to uneven coverage and can result in missed areas and excess heating due to pulse stacking. SOE (Scanner Optimized Efficacy) technology eliminates these problems by utilizing computer-controlled laser scanner mirrors to automatically place a 3 mm spot size laser beam in a non-sequential pattern [19-20].

b) Twinlight™ skin resurfacing method

The variable square pulse (VSP) Er:YAG laser (2940 nm) has been successfully used for ablative epidermal skin resurfacing [21]. Due to the Er:YAG laser's high absorption in water, this laser easily achieves temperatures above 100^0C resulting in a photo-vaporization effect in the superficial skin layers. This heating effect may generate also relatively deeper photo-coagulative (<99^0C - > 55^0C) and photo-biostimulating (<50^0C) effects along the penetration tail. However, the Er:YAG's main photo-thermal "core" action concentrates on the superficial (<100 µm) layers of the skin [21]. On the other hand, the Nd:YAG laser wavelength (1064 nm), due to its non-specific protein-water absorption and scattering within epidermal-dermal tissue, concentrates its highest photon density and therefore its main photo-thermal core 1-3 mm below the skin surface [6-7].

The Twinlight™ skin resurfacing treatment combines the two complementary photothermal "core" treatments (Nd:YAG and Er:YAG) in one successively performed treatment protocol [11]. In the first step, the skin is treated with Nd:YAG laser *FRAC3®* photo-thermal therapy. Sometimes, this first step includes also an additional treatment with a long pulse Nd:YAG laser. The goal of this first, Nd:YAG laser step is twofold: a) to improve photo-induced skin textural alterations through neo-collagenesis and b) to improve the wound healing process following Er:YAG laser skin resurfacing. In the second step, a fractional Er:YAG treatment is performed (See Fig. 2).

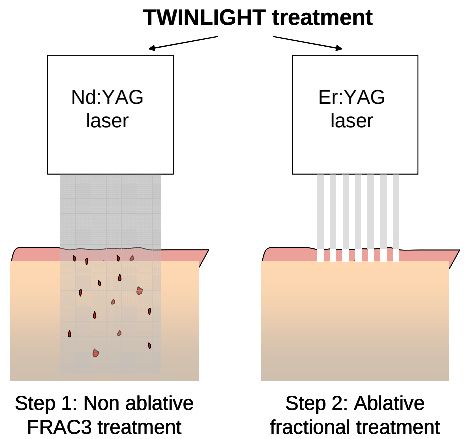

Fig. 2: The Twinlight™ skin resurfacing treatment combines two complementary fractional laser procedures into a single, synergistic action. In step 1, the skin is subjected to a deep non-ablative FRAC3 photothermal therapy with Nd:YAG laser. In step2, the skin epidermis is fractionally ablated with Er:YAG laser.

III. CLINICAL RESULTS

a) Clinical experience with *FRAC3®* skin rejuvenation

Animal studies have shown that the primary targets of non-ablative Nd:YAG rejuvenation are 100 um to 500 um below the surface of the skin [22]. They have also shown that Nd:YAG light can penetrate into the deeper levels of the recticular dermis. The primary changes in the level of collagen formation were seen in the recticular, not the papillary dermis, this is because of the depth of penetration of the Nd:YAG laser. Parameters used were 30 J/cm², 0.3 ms, and 6 mm. Biochemical studies have also shown that 1064 nm light with FRAC3® characteristics caused a 47% increase in collagen type I and a 16% increase in collagen type III in a mouse model [23]. Human studies have confirmed what these animal studies have shown exhaustively, as is cataloged in the sections which follow.

FRAC3® skin rejuvenation parameters are fixed within a narrow range (i.e. 0.1-0.4 ms, 10-35 J/cm²) but this range has been found to yield good results for even the darkest skin types [8]. However varying approaches are needed, because the effects in light and dark skin types are different. The difference in the surface skin temperature rise between light and dark skin types is significant, varying by a factor of 2 upon irradiation with 1064 nm [5]. Even among patients of the same Fitzpatrick phototype the effects of laser light can vary by up to 10°C for the same parameters. This is in part due to the fact that the Fitzpatrick phototype is a measure of the skins response to sunlight and not directly of the skins melanin concentration [24]. The differences between temperature rise and skin type are even more dramatically illustrated by the fact that the ratio of temperature rise for a 10 ms Nd:YAG pulse and a 0.3 ms pulse can vary from 4 to 12; with lighter skin types seeing the greates differences [5].

The *FRAC3®* effect is much more pronounced in light skin types then in dark skin types. When considering the effect of *FRAC3®* specifically on areas of micro damage European skin types see 40% more relative heating than Indian and Japanese Skin Types [5]. This leads to the conclusion that, as in much of the rest of laser medicine, higher fluences can be used on lighter skin.

The levels of pain due to the epidermal heating alone, as experienced in Nd:YAG laser treatments are tightly correlated with spotsize but largely independent of pulsewidth. In the light phenotypes studied in [5] the threshold of pain level was approximately 60 J/cm2 for a 6 mm spotsize (at 0.3 ms pulse) and 100 J/cm2 at a 3 mm spotsize (at 0.3 ms pulse). The values for dark skin types would be lower because the thermal retention time of epidermis can be between 1 ms and 100 ms. This data explain help explain why the parameters normally used for *FRAC3®* skin rejuvenation are acceptable for dark skin types [8,10].

Using *FRAC3®* parameters Koh and co-workers evaluated *FRAC3®* parameters on high-phototype (Korean) patients [10]. They found improvements in text, dyschromia, degree of wrinkling, and erythema. This study stands out for its use of mechanical and electronic means to assess sebum production, skin roughness, pigmentary and erythemic improvement. Sebum production was stable before and after treatment, while pigmentation and skin roughness improved. Koh treated 12 Korean women 5 times, with treatments spaced 3 to 6 weeks apart using parameters of 13-14 J/cm2, 0.3 ms pulse durations, 5 mm spotsize, at 7 Hz. No patients in this study developed any significant side effects as a result of Frac3 photorejuvenation. Some patients developed temporary erruptions and miliaria.

Trelles performed a similar study, but only performed three treatments, spaced two weeks apart [9]. Out of 10 patients 6 showed fair improvement in skin texture, 4 showed good improvement. 70% of patients were either fairly or very satisfied at the 6 month follow up point. In line with conclusions from other studies, including Koh's, Trelles found that collagen remodeling was a gradual process lasting from 6 to 12 months. Trelles used 3 to 10 mm spotsize, 13 J/cm2, a pulse width of 0.3 msec, and repition rates of 7 Hz; no anesthesia was used. The erythema experienced by patients disappeared within 24 to 48 hours of treatment. As part of this study histologies were taken from 4 patients, once before treatment and two months after the last treatment. Histology showed that the treatment had caused a thickening of the epidermis, caused the stratum corneum to become more compact, and that the dermis was much better organized.

In addition to histological, and gross anatomical analysis, electron micrographs have also been used to analyze the effects of *FRAC3®* parameters on the skin [12]. EM analysis showed that that the percentage of collagen fibers having small widths increased between 1 and 3 months after the *FRAC3®* treatment. This effect was especially pronounced in younger patients and suggests that new collagen is being produced. The authors postulate that a lack in the decrease of collagen fiber width (on a percent of total basis) in older patients may have been due to elastosis that could block laser energy. This effect was evident in the two oldest patients in the study (58 and 67). The other 8 women who participated in this study did not exhibit this effect. The age range across all 10 women was 28-67, all had at least some evidence of fine lines with Erythema and had Fitzpatrick phototypes I-III. Treatments were given across 3 sessions spaced at 2 week intervals with settings of 0.3 msec, 5 mm spotsize and 7 to 9 J/cm^2; no cooling or anesthesia was used. The authors note that no adverse events were reported as a result of these parameters. It should be noted that this is probably because the investigators used low parameters in the 12-16 J/cm^2 range. The effects of induced collagen growth seen in this study would probably increase if greater parameters were used.

The decreases seen in erythema in the previously mentioned studies are explained by some authors as follows: *FRAC3®* pulsewidths are short enough to target the microvasculature and thereby act on erythema. Nd:YAG light is effective against a wide range of blood vessels, from reticular veins to capillaries, if the pulse duration is properly adjusted [25]. The effect of *FRAC3®* on erythema was investigated by Groot. In his clinical study he found that 77% of blinded evaluators greatly preferred the before pictures to the after pictures. In this study 14 female patients (skin types I-IV) were treated with 0.3 ms, 13-20 J/cm^2, 5 mm spotsize, with 7000 pulses over the entire face in six treatments spaced 2 to 6 weeks apart. No anesthetic or cooling was used, no special post operative care was needed. The *FRAC3®* treatment parameteres used in this treatment heated the skin to the low 40⁰C range, this temperature was maintained for 60 seconds.

b) Clinical experience with Twinlight™ skin resurfacing

The Twinlight™ skin resurfacing treatment (TRT) combines two complementary fractional laser procedures into a single, synergistic action.

In an earlier approach, Badawi [8] combined dermabrasion with *FRAC3®* treatment parameters in a study investigating scar revision. In addition to scar revision, the *FRAC3®* parameters were able to improve PIH from acne scarring and skin texture. *FRAC3®* treatment did not induce new PIH and did not require anesthetic or chemical agents to control PIH, despite the fact that all patients were of dark phototype (III-VI). Nd:YAG laser pulsewidths between 0.3-0.5 msec were used, along with 5 mm spotsizes, 5-10 Hz repetition rate and a fluence of 14-16 J/cm². This treatment was given 5 to 7 times to each patient, dermabrasion was performed a few days before each laser session. No patients reported any adverse effects. Badawi et. al. Intentionally avoided skin cooling, stating that the gradual increase in skin temperature caused by the treatment enabled safe treatment of dark skin types. It is to be noted that blistering, crusting, purpura, and scarring did not occur. Thus, *FRAC3®* in combination with dermabrasion, was found to be safe and effective fro the treatment of atrophic acne scarring.

Marini [11] combined Er:YAG resurfacing with Nd:YAG non-ablative rejuvenation. This combined approach to skin rejuvenation was successful, and, based on the author's experience, it appears that the use of the combined modality was both complementary and additive. Nine out of 10 patients showed substantial improvement in skin texture. Patients also self-evaluated their own progress as substantial at 1 and 2 months after treatment. All patients showed a high degree of satisfaction. Marini studied a large parameter range in order to optimize his treatment. Each of the 10 patients was exposed to multiple parameter sets through the use of distinct treatment areas. The protocol consisted of 1 pass of *FRAC3®* treatment parameters, 1 pass of long pulse Nd:YAG, 1 pass of fractional short pulse ablative Er:YAG, and two passes of full beam Er:YAG light. Marini provides evidence and arguments that combination therapy yields synergistic positive effects on critical skin parameters. Due to the ablative nature of the full beam Er:YAG portion of the protocol the side effects seen by Marini are much harsher then those seen by other authors.

In a more recent study, Marini compared histological results following single Nd:YAG or Er:YAG treatments with those obtained with a combined, Twinlight treatment. Histologic findings confirmed the validity and effectiveness of a sequential multilayer fractional resurfacing and remodeling procedure combining 1064 nm Nd:YAG and 2940 nm Er:YAG lasers over single, isolated laser treatments.

In another study, clinical results following single laser fractional ablative Er:YAG laser resurfacing alone were compared with clinical results following a combined, Twinlight skin resurfacing treatment. The combined method was found to be clinically and histologically superior to single wavelength (2940 nm) fractional resurfacing alone. Two groups of Fitzpatrick skin type II-III subjects affected by mild photo- and chrono-aging were enrolled in his study. Group A (55 subjects) was treated with a sequence of *FRAC3®* and long pulse 1064 nm Nd:YAG laser (0.3 ms-35 J/cm² scanner operated 3 mm spot followed by 35ms-50J/cm²-scanner operated 3mm spot) immediately followed by two 2940nm Er:YAG laser passes in a fractional mode (600µsec-12J/cm²-scanner operated 0.25mm spot); Group B (45 subjects) was treated with two 2940nm Er:YAG laser passes in a fractional mode (600µsec-12J/cm²-scanner operated 0.25mm spot). Standardized clinical photographs were taken (D0-D+30-D+60-D+90). Blind evaluation of clinical photographs by two dermatologists obtained 90% concordance level. Overall clinical improvement was considered higher (37%) in Group A compared to Group B subjects. Group A showed also better improvement of epidermal dyspigmentation (25%); rhytides (35%); and skin laxity (38%) when compared to Group B at D+90. Collagen fibers positive rearrangement were found more prominent (32% D+90); flattening of rete ridges more evident (20% D+90); and epidermal thickness positive rearrangement more pronounced (30% D+90) in Group A. Intra-operative and immediately post-operative symptomatological acceptability reported by patients was 85% in Group A and 87% in Group B. Subjective clinical perception of overall skin improvement at D+90 was higher (78%) in Group A than in Group B (62%).

IV. CONCLUSIONS

Two latest skin rejuvenation laser methods, *FRAC3®*and Twinlight™, were reviewed.

The efficacy of *FRAC3®* rejuvenation has been demonstrated histologically, electron micrographically, through physiological measurements of skin parameters, through blinded assessment of before and after pictures, and by patient satisfaction. *FRAC3®*can be used to rejuvenate skin in every Fitzpatrick phototype.

On average, investigators using *FRAC3®* parameters for skin rejuvenation used a 0.3 ms pulsewidth, 13-16 J/cm^2, and 3-5 mm spotsize. Minimally three treatment sessions are needed, but results are better if the patients are given 6 treatment sessions.

When more pronounced effects are desired or required, non-ablative *FRAC3®* Nd:YAG laser rejuvenation can be successfully combined with ablative fractional Er:YAG treatment strategy using the Twinlight™ skin resurfacing method. Clinical and histological studies have demonstrated that the superiority of the Twinlight™ skin resurfacing method is due to the synergistic positive effects of the two wavelengths. Twinlight™ treatment is superior both in comparison with single non-ablative Nd:YAG and single ablative fractional Er:YAG laser treatment.

REFERENCES

1. Manstein D, Herron GS, Sink RK, et al. Fractional photothermolysis: a new concept for cutaneous remodeling using microscopic patterns of thermal injury. Lasers Surg Med., 2004; 34:426-38.
2. *FRAC3®* is a Fotona trademark (www.fotona.com) for the self–induced three-dimensional fractional treatment approach in laser skin treatments.
3. M. Gorjan, L. Grad, M. Lukac. Three Dimensional Fractional Laser Skin Rejuvenation, IMCAS, 2008; Abstracts Booklet 28.
4. Lukac M, Sult T, Zabkar J, Gorjan M, Vizintin Z. Parameters for the New FRAC3 Nd:YAG Laser Skin Treatment Modality. J. Laser Health Academy, 2010; 1:47-55, www.laserandhealth.com.
5. Lukac M, Zabkar J, Gorjan M, Sult T. FRAC3: Three Dimensional Non-Ablative Fractional Laser Skin Rejuvenation. J. Laser Health Academy, 2009; 2:20-3. www.laserandhealth.com.
6. Lukac M, Zabkar J, Gorjan M, Vizintin Z. 2010, Beyond Customary Paradigm: Self-Induced Fractional Nd:YAG Laser Hair Removal, J. Laser Health Academy, 2010; 1:35-46. www.laserandhealth.com.
7. RR. Anderson, J.A. Parrish. Selective Photothermolysis-precise Microsurgery by Selective Absorption of Pulsed Radiation, Science, 1983; 220:524-7.
8. Badawi A, Tome MA, Atteya A, Sami N, Morsy IA. Retrospective analysis of non-ablative scar treatment in dark skin types using the sub-millisecond Nd:YAG 1,064nm Laser. Lasers Surg Med., 2011; 43(2):130-6.
9. Trelles MA, Álvarez X, Martín-Vázquez MJ, Trelles O, Velez M, Levy JL, Allones I. Assessment of the Efficacy of Nonablative Long-Pulsed 1064-nm Nd:YAG Laser Treatment of Wrinkles Compared at 2, 4, and 6 Months. Facial Plast Surg., 2005; 21(02):145-53.
10. Koh BK, Lee CK, Chae K.. Photorejuvenation with Submillisecond Neodymium-Doped Yttrium Aluminum Garnet (1,064 nm) Laser: A 24-Week Follow-Up. Dermatol Surg., 2010 ; 36(3):355-62.
11. Marini L. SPF-RR sequential photothermal fractional resurfacing and remodeling with the variable pulse Er:YAG laser and scanner-assisted Nd:YAG laser. J Cosmet Laser Ther, 2009; 11(4):202-11.
12. Schmults CD, Phelps R, Goldberg DJ. Nonablative Facial Remodeling: Erythema Reduction and Histologic Evidence of New Collagen Formation Using a 300-Microsecond 1064-nm Nd:YAG Laser. Arch Dermatol., 2004; 140(11):1373-6.
13. Marini L. Sequential Photothermal 1,064 Nd:YAG and 2,940 nm Er:YAG Fractional Resurfacing and Remodelling versus 2,940 nm Er:YAG Fractional resurfacing Alone: a Comparative Study, Lasers Surg Med., 2011; 43:949.
14. Marini L. Thermo-Fractional PDT for Peristent Warts, Lasers Surg Med., 2011; 43:939.
15. Marini L. Sequential Photothermal 1,064 Nd:YAG and 2,940 nm Er:YAG Fractional Resurfacing and Remodelling versus 2,940 nm Er:YAG Fractional resurfacing Alone: a Comparative Study, J. LAHA, 2011; 1, www.laserandhealth.com.
16. Marini L. Twinlight Rejuvenation Technique (Nd:YAG+Er:YAG) vs Er:YAG Resurfcaing Alone: a Comparative Study, J. LAHA, 2011; 1, www.laserandhealth.com.
17. Dierickx CC. The role of deep heating for noninvasive skin rejuvenation. Lasers Surg Med., 2006; 38(9):799-807.
18. Moritz AR. Henriques FC. Studies of Thermal Injury. Am J Pathol ., 1947; 23(5):695-720.
19. M. Lukac, L. Grad. Scanner Optimized Aesthetic Treatments with the VSP Nd:YAG Lasers. J. Cosmet Laser Ther, 2008; 10(2).
20. Scanner Optimized Efficacy (SOE) is a Fotona d. d. (www.fotona.com) proprietary technology for perfectly covering large skin areas with optimally sized individual beam spots.
21. Lukac M, Perhavec T, Nemes K, Ahcan U. Ablation and thermal depths in VSP Er:YAG laser skin resurfacing. J Laser Health Academy, 2010; 1:56-71, www.laserandhealth.com.
22. Dayan S, Damrose JF, Bhattacharyya TK, Mobley SR, Patel MK, O'Grady K, Mandrea S. Histological evaluations following 1,064-nm Nd:YAG laser resurfacing. Lasers Surg Med., 2003; 33(2):126-31.
23. Liu H, Dang Y, Wang Z, Chai X, Ren Q. Laser induced collagen remodeling: A comparative study in vivo on mouse model. Lasers Surg Med., 2008; 40(1):13-9.
24. Verkruysse W, Jia W, Franco W, Milner TE, Nelson JS. Infrared measurement of human skin temperature to predict the individual maximum safe radiant exposure (IMSRE). Lasers Surg Med., 2007; 39(10):757-66.
25. Groot D, Smith K. Non-Ablative Skin Therapy with CoolGlide Vantage Sub-Millisecond 1064 nm Laser Treatments. Cutera, Oct. 2002; D0074, Rev. B.