Novel Fractional Treatments with VSP Erbium YAG Aesthetic Lasers

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ABSTRACT:

Indications for use of the Er:YAG laser are continuously expanding. In this paper, the latest Pixel Screen Technology (PST) fractional technique for minimally invasive Er:YAG skin rejuvenation is presented. The fractional technique is based on a concept of producing an array of microscopic wounds on the skin surface that are rapidly reepithelialized by the surrounding, undamaged tissue, thus sparing the epidermis. The advantage of PST compared to other fractional technologies is that it allows the quality and the parameters of the laser beam within the pixels to remain unchanged compared to the basic beam properties. This enables the practitioner to perform nine basic ablative and one non-ablative treatment at fully clinically tested laser parameters. PST provides another dimension in the treatment of various skin conditions, avoiding some of the adverse effects of ablative laser procedures while improving the limited efficacy of the non-ablative treatments. The combination of Fotona's latest Er:YAG technologies, presented in this paper (SMOOTH mode, PST and TURBO mode), provide the practitioner with an unequaled 11 basic and 11 fractional treatment modalities.

Key words: fractional, laser resurfacing; VSP technology, mini peels, SMOOTH treatments, Er:YAG lasers, scanner, TURBO mode.

INTRODUCTION

The abundance of facial skin care regimens and their enthusiastic promotion in popular media is the modern expression of an ancient desire to attain beauty and recapture a youthful appearance. As the face ages, skin quality deteriorates. One method of improving the condition of the skin is by "resurfacing" it, i.e. by removing the outer layers to the level of the papillary dermis. Removing the outer skin layers to papillary dermis level induces re-epithelialisation and new collagen formation, which can create a smoother, even-toned, and more youthful appearance. In the late 1980s, laser technology applied to skin resurfacing was discovered to yield more predictable depths of injury when compared with chemical peels or dermabrasion. The first laser used for skin resurfacing was a pulsed carbon dioxide (CO_2) laser. Later, the erbium:yttrium-aluminum-garnet (Er:YAG) laser was introduced, which has now become a standard tool for skin resurfacing [1,2].

The cutaneous absorption of the Er:YAG laser energy by water is 10-fold more efficient than that of the carbon dioxide laser, allowing for more superficial tissue ablation and finer control. The latest Variable Square Pulse (VSP) technology Er:YAG lasers have variable pulsewidths allowing the practitioner to select the effect of the laser from "cold" ablation peeling to deeper thermal coagulation. [3-6] Indications include mildly photo-damaged skin lesions (e.g. solar keratoses), mildly atrophic facial scars (e.g. from acne or varicella), dyschromias (e.g. melasma, lentigines), and mild-to-moderate facial wrinkles in the perioral, periocular, and cheek areas. The newer Er:YAG lasers with longer and variable pulses allow patients with deeper wrinkles and scars to be successfully treated.

Many other skin lesions have been successfully treated with the Er:YAG laser, including compound nevi, sebaceous hyperplasia, trichoepitheliomas, miliary osteomas, syringoma, telangiectasia, rhinophyma, adenoma sebaceum, hidradenoma, xanthelasma, and the cutaneous manifestations of Hailey-Hailey disease and Darier disease [7-10].

Indications for use of the Er:YAG laser are continuously expanding. For example, recently an Er:YAG laser operating in a non-ablative SMOOTH mode for new collagen synthesis has been introduced [11-24].

Fractional laser photothermolysis is the latest in the broad range of Er:YAG laser techniques. This technique promises a novel means of providing treatments that would be as effective as traditional Er:YAG approaches while further reducing their downtime and risk [25-27]. The fractional technique is based on a concept of producing an array of microscopic wounds on the skin surface that are rapidly reepithelialized by the surrounding, undamaged tissue, sparing the epidermis in the untreated areas. Here, we describe the latest PST (Pixel Screen Technology) fractional technique for minimally invasive Er:YAG skin rejuvenation.

BASICS OF ABLATIVE LASER SKIN TREATMENTS

Wavelength is a key factor in the suitability of any laser for ablative skin procedures in aesthetics. There are currently three medical laser technologies, namely Er:YAG, Er:YSGG (or Er,Cr:YSGG) and CO_2, whose laser wavelengths operate in the regions of the major absorption peaks for water (see Fig.1). Since the skin consists of 70% water, these three laser types can be effectively used for skin tissue ablation treatments.

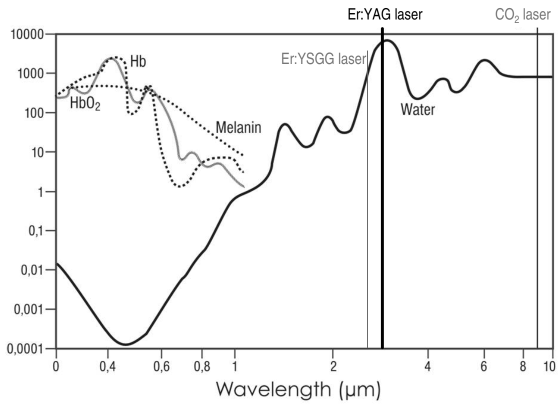


Fig. 1: The Er:YAG (2.9 µm) laser has the highest absorption in water and consequently in human skin. The Er:YSGG (2.7 µm) wavelength is located slightly below the water absorption peak, and is for this reason already 3 times less absorbed in human skin. An alternative laser that emits in the high absorption region is the CO_2 laser (9.6 µm), however this laser is still 10 times less absorbed in water and is thus least suitable for laser resurfacing.

There are three steps in tissue heating upon laser irradiation. The tissue is first heated directly within the optical absorption depth (*direct heating*). As we will see below, the minimum depth of coagulation is dependent on the optical absorption depth.

Direct heating is followed by thermal diffusion that indirectly heats the deeper lying tissues (*indirect heating*). For shorter pulses, the time span for thermal diffusion is short, and the temperature does not reach very deep into the tissue. For longer pulses, the heat has sufficient time to spread deeper into the tissue.

In the third step, the hottest part of the tissue close to the surface is evaporated, in effect reducing the depth of the thermally affected skin layer.

Closer study of the absorption peaks associated with Erbium lasers shows a 300% difference between the absorption coefficients in human skin of Er,Cr:YSGG (100 mm^{-1}) and Er:YAG (300 mm^{-1}). Similarly, the absorption coefficient, µ of the CO_2 laser is approximately 1000% smaller compared to that of the Er:YAG laser. The Er:YAG laser wavelength thus penetrates approximately $1/\mu = 3$ µm in the skin, while the Er:YSGG laser and CO_2 laser wavelengths respectively penetrate 10 µm and 30 µm into the skin (see Fig. 2).

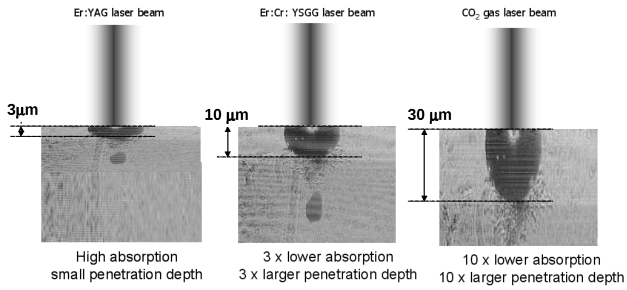


Fig. 2: The optical penetration depths in skin for the three ablative laser types. Depending on the laser type, different volumes of the illuminated tissue are directly heated by the laser light.

This difference influences the volume of tissue directly heated by the laser to ablative temperatures, before the energy is diffused into the surrounding tissue. The optical penetration depth thus determines the smallest possible depth of skin coagulation. While the coagulation depth can be increased through indirect heating, it cannot be reduced below the optical penetration depth (see Fig. 3).

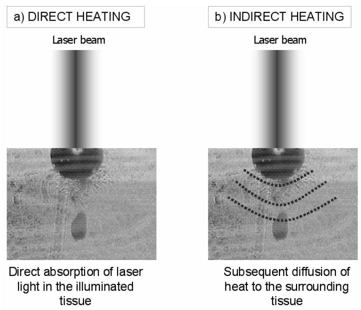


Fig. 3: Direct and indirect heating upon laser irradiation. The tissue is first heated directly within the optical absorption depth. This is followed by thermal diffusion that indirectly heats deeper lying tissue. The directly heated optical absorption depth layer is the smallest achievable coagulation layer in the skin.

A key factor that determines the indirect heating depth, and therefore the laser treatment regime, is the laser pulsewidth. If the energy is delivered to the target in a very short time, ablation occurs before significant heat diffusion can take place. This results in less heat being distributed to the surrounding tissue. On the other hand, a long pulsewidth will allow more heat transfer before ablation takes place resulting in a greater thermal effect on the surrounding tissue.

As an example, Figure 4 shows the coagulation depth d_c at which the skin is indirectly heated to above 70^O C, when laser fluences close to the ablation threshold are used (i.e. in a hot ablation regime). The coagulation depth was calculated from the characteristic diffusion depth $x_d = (4D\ t_p)^{1/2}$, in which t_p is the laser pulsewidth, and the diffusion constant D for the skin is taken to be $1{,}1 \times 10^{-7}$ m^2/s [29].

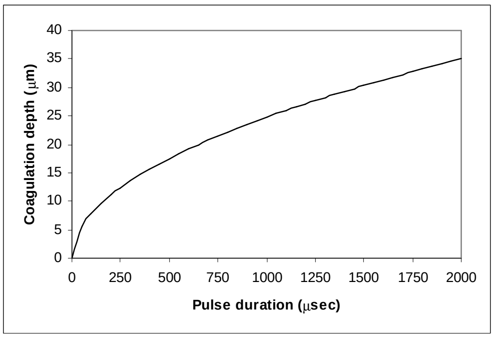


Fig. 4: The dependence of the skin coagulation depth on the laser pulsewidth.

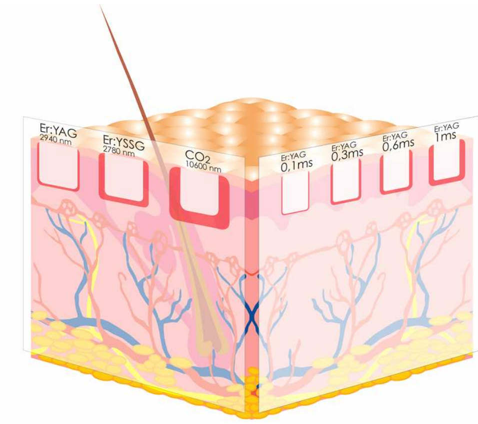


Fig. 5: By varying the Er:YAG laser pulsewidth it is possible to achieve coagulation depths of the Er:YSGG and CO_2 lasers. The latter two laser sources are limited to larger coagulation depths only.

It can be concluded from Figure 4 that the coagulation depth can be controlled by varying the laser pulsewidth. This is subject to the limitations of each particular laser technology and wavelength. For example, for the Er,Cr:YSGG laser an additional limitation applies due to the slow Cr-Er cross-relaxation times. As a result, the shortest achievable pulsewidths of Er,Cr:YSGG lasers are in the 500 µsec range[30-31], limiting its adjustable coagulation depth range only to 17 µm and beyond.

When we take into account the optical penetration depths of the three ablative sources, we observe that the Er:YAG laser allows coagulation depth control from 3 µm (Fig. 6a) and beyond, while the Er,Cr:YSGG and CO_2 lasers are limited to larger coagulation depths, respectively beyond 17 µm (Fig. 6b), and 30 µm (Fig. 6c).

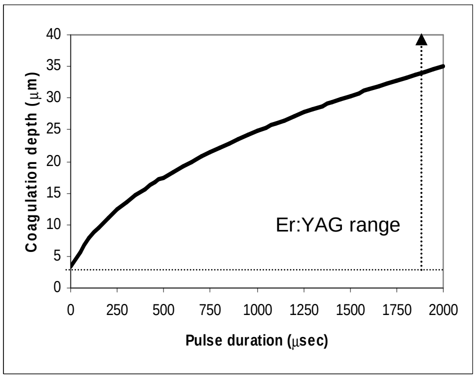


Fig. 6a: Er:YAG has the largest adjustable coagulation depth range: from beyond 3 µm.

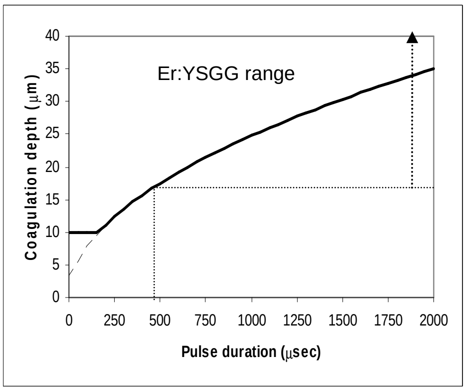


Fig. 6b: Er:YSGG adjustable coagulation depth range: from beyond 17 µm only.

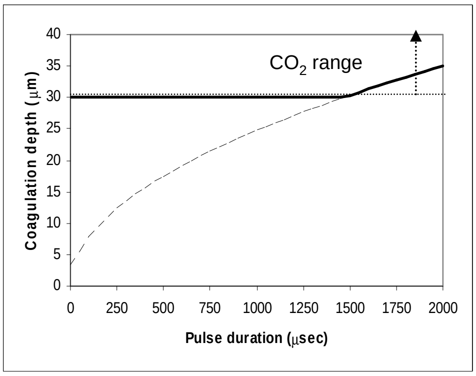


Fig. 6c: CO_2 adjustable coagulation depth range: from: beyond 30 µm only.

Here, the Er:YAG laser is at an advantage as it allows the largest range of coagulation depth control, and therefore the most complete range of treatments. By adjusting laser parameters, the Er:YAG laser can thus be used to perform "Er:YAG" type, as well as "Er:YSGG" and "CO_2" type laser treatments. Similarly, the Er:YSGG laser can be made to emulate the effects of the CO_2 laser, while the CO_2 laser is limited to the "CO_2 " type treatments alone (See Fig. 5).

Practitioners have long used carbon dioxide (CO_2) lasers for facial resurfacing treatments. CO_2 laser devices can be effective for this purpose, but a considerable number of post-operative issues with the laser source have been reported. The reason lies in the larger coagulation depth of the CO_2 laser wavelength. Therefore, Er:YAG lasers have almost completely replaced CO_2 lasers for skin resurfacing procedures. Recently, Er:YSGG lasers have also been introduced. But as previously demonstrated, they are indicated for warm and hot laser treatments only.

As discussed above, the laser light's ablative energy must be delivered to the skin in a temporal pulse of appropriate duration in order to control skin heating and ensure the efficacy, efficiency and safety of treatments. In the case of a long laser pulse or continuous irradiation, the heat that is generated by the laser light has sufficient time to diffuse deeper into the tissue from the irradiated surface area. This results in higher thermal effects inside the skin. To generate high energy light pulses most devices use a standard PFN (Pulse Forming Network) technology. PFN pulses have a typical temporal shape with a slow rise time and a relatively long declining tail. The pulse power is not constant during the pulse and the exact pulsewidth is not defined. More advanced VSP (Variable Square Pulse) [3] technology generates pulses that provide much higher treatment precision, efficacy and safety [4-5]. A significant difference between the two pulse types is that for square pulses the average power and the peak power are nearly the same, which cannot be said for PFN-generated pulses. This means that the effect of VSP pulses on the skin is far more predictable than PFN pulses. This ultimately leads to superior treatment outcomes, with less discomfort for the patient and fewer side effects.

BASIC VSP Er:YAG LASER TREATMENT REGIMES

In laser ablation we generally talk about three ablative and one non-ablative treatment regimes [28]. At high energies and low pulsewidths (i.e. at high laser pulse powers), the ablation speed is higher than the rate at which heat diffuses into the tissue. All laser energy is thus used up for COLD ABLATION (see Fig. 7). The thermally affected tissue layer is confined to the directly heated tissue volume within the optical penetration depth. With decreasing energies and/or longer pulsewidths (i.e. with lower laser pulse powers), the tissue layer that has been indirectly heated becomes thicker. Thermal effects become more pronounced, leading to WARM ABLATION and, at even lower energies to HOT ABLATION. At energies below the ablation threshold there is NO ABLATION and all the energy is released as heat, irrespective of the laser pulsewidth.

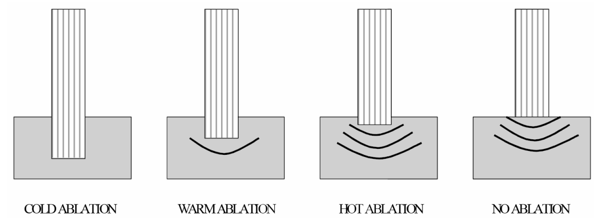


Fig. 7: The effect of the laser beam on tissue in the four treatment regimes.

The coagulation and ablation depths depend on the combination of three parameters; laser wavelength, pulsewidth and fluence (i.e. the laser energy per surface area in J/cm^2). The VSP technology-supported Er:YAG laser is an extremely versatile and precise skin resurfacing tool. The control of pulsewidth and laser fluences provides a wider range of treatment options that can be depicted as a simple matrix (see Fig. 10).

VSP Er:YAG laser treatment regimes are thus defined as follows (also see Fig. 8):
a) **Cold regime** with coagulation depths of approximately 3-7 µm;
b) **Warm regime** with coagulation depths of approximately 8-15 µm;
c) **Hot regime** with coagulation depths above approximately 15 µm.

Er:YAG Thermal Regime	Coagulation Depth (µm)
COLD	3 – 7
WARM	5 – 15
HOT	above 15

Fig. 8: Three VSP Er:YAG laser thermal treatment regimes.

Note that the VSP Er:YAG cold, warm and hot regimes correspond approximately with the coagulation depth limits of the Er:YAG (cold), Er:YSGG (warm) and CO_2 (hot) lasers (see also Fig. 7). By selecting VSP Er:YAG laser regimes, the practitioner tunes the laser effect from a purely "Er:YAG type" laser treatment, to an "Er:YSGG type" laser treatment, and at the longest pulsewidths to a "CO_2 type" laser treatment.

There are also three VSP Er:YAG laser treatment regimes (*Light*, *Medium*, and *Deep*) in terms of their ablative depth (see Fig.9):

Er:YAG Ablative Regime	Ablation Depth (µm)
LIGHT	0 – 5
MEDIUM	6 – 20
DEEP	above 20

Fig. 9: Three Er:YAG ablation regimes in terms of ablation depth..

The combination of Er:YAG thermal treatment regimes with the treatment regimes based on ablation depth provides a matrix of nine VSP treatment regime option, as shown in Figure 10. The approximate ablative and coagulative depths for the nine regimes are shown in Figure 11. The recommended treatment parameters for the nine regimes are shown in Figure 12.

Note that the recommended values are only approximated, as the exact values depend on skin type, treatment location, skin hydration levels and other parameters. The ablation threshold fluence of approximately 1 J/cm² can thus vary in real patient situations between 0.4 and 1.5 J/cm². Also note that the indicated boundaries between the regions of cold, warm and hot ablation are only approximate. In reality more gradual transitions exist between these treatment regimes.

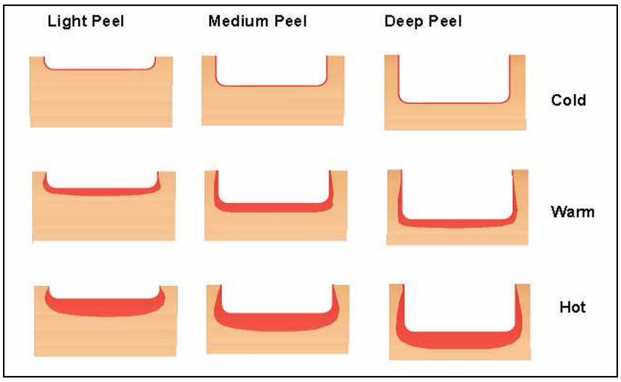


Fig. 10: Nine basic VSP Er:YAG laser treatment regimes.

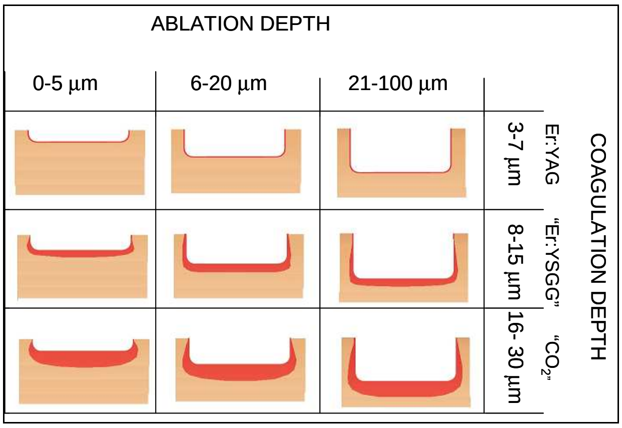
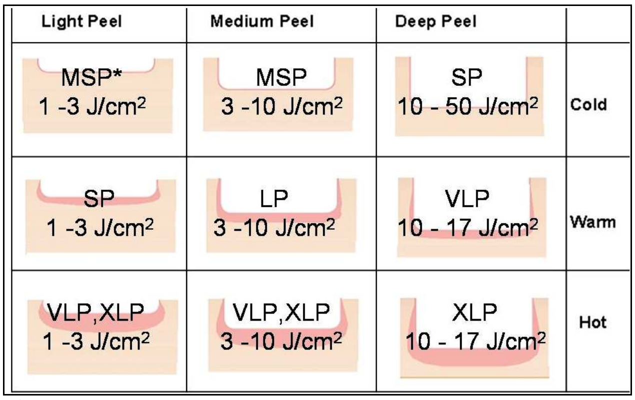


Fig. 11: Approximate ablative and coagulative depths for the nine VSP treatment regimes.



* MSP mode is equivalent to VSP mode in some models

Fig. 12: Recommended treatment parameters for the nine VSP Er:YAG treatment regimes.

The correct therapeutic ablation depth is the minimum depth needed to achieve the desired clinical result, whether it is for the effacement of rhytids, removal of photo-damage and/or collagen tightening. Generally, laser resurfacing is performed by treating the area completely, until the to-be-removed lesions have been ablated or until punctate bleeding appears, which indicates the papillary dermis has been reached. At the papillary dermis level a maximum therapeutic effect is achieved with a minimum risk of side effects. Continuing to treat deeper than the papillary dermis has minimal clinical benefits, while the potential of complications and side effects may even exponentially increase. With clinical experience it is advisable to select laser treatment settings that will give the desired result in 2-4 passes. Visual clinical end-points for the three ablative regimes are shown in Figures 13a to 13c.

Light Peel

Fig. 13a: Light Peel. Whitish coloring of the skin after administering laser pulses generally indicates the Er:YAG laser treatment has reached the intra-epidermal level.

Medium Peel

Fig. 13b: Medium peel. Yellowish coloring of the skin after administering laser pulses generally indicates the Er:YAG laser treatment has reached the deep epidermal level

Deep Peel

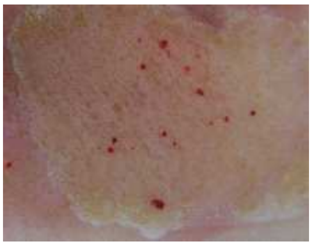


Fig. 13c: Deep peel. Punctate bleeding suggests that the papillary dermis has been reached. Generally this indicates that the clinical end-point has been reached in Er:YAG laser resurfacing treatments.

As a general rule, the final treatment outcome is more pronounced when more aggressive treatment parameters are used. More aggressive treatments are achieved with deeper ablation and coagulation parameters while patient downtime and risk of complications increase. An approximate relation of the nine treatment regimes with regards to the efficacy and downtime is shown in Figure 14. Clinically obtained downtimes for cold, warm and hot light peels are respectively 12-48 hours, 12-72 hours, and 4-5 days. The downtime for a *cold medium peel* (papillary dermis) is 7-10 days.

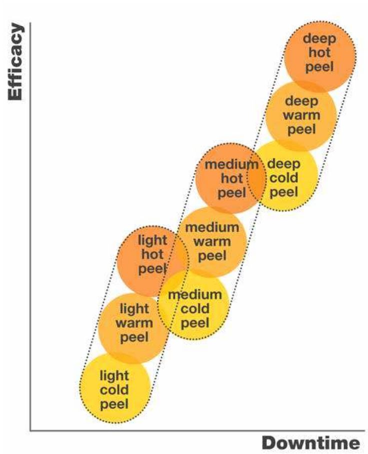


Fig. 14: Approximate relation of the nine VSP Er:YAG laser ablative treatment regimes with regard to the efficacy and downtime.

NON-ABLATIVE FOTONA SMOOTH MODE

In addition to the nine basic VSP Er:YAG treatment regimes, Fotona has developed a unique additional tenth treatment regime; the non-ablative SMOOTH mode (see Fig. 15).

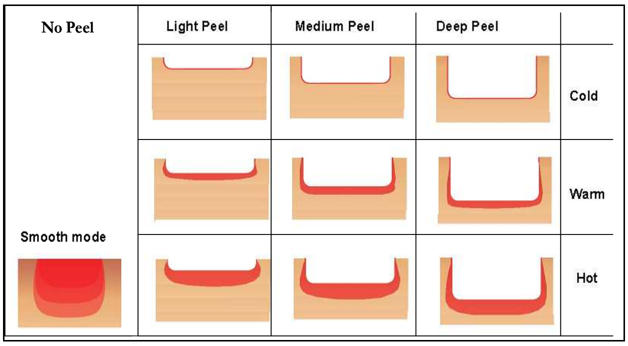


Fig. 15: A non-ablative Fotona SMOOTH mode is available in addition to the nine VSP Er:YAG ablative treatment regimes.

In the Fotona SMOOTH mode, laser energy is transmitted as heat onto the skin surface, without any resulting ablation, and is then dissipated into the deeper tissue layers. If laser energy is delivered to the skin surface in a time period longer than the Thermal Relaxation Time (TRT) of the epidermis (estimated to be between 1 and 10 msec depending on the thickness), the epidermis has sufficient time to cool by dissipating the heat into the deeper skin layers. Thus temperatures required for ablation are never reached. The TRT is the time required for the tissue temperature to decrease by approximately 63%. And if at the same time laser energy is delivered in a time period that is shorter than the combined skin TRT (estimated to be in the range of 500 msec) then the skin does not have time to cool off during the laser pulse. The delivered laser energy thus results in an overall build-up of heat and creates a temperature increase deep in the papillary dermis.

The above principle is employed when the super-long pulses of SMOOTH mode are used. SMOOTH pulses deliver laser energy onto the skin in a fast sequence of low fluence laser pulses inside an overall super-long pulse of 200-350 msec. Because the super-long SMOOTH pulses are longer than the epidermal TRT, the threshold ablation fluence is much higher than 0.7 J/cm^2 and the conditions for ablation are never reached. The effect of SMOOTH mode is only coagulative heating of the skin, without any significant ablation of the epidermis. The estimated coagulation depths d_c in SMOOTH mode as a function of laser fluence, are shown in Figure 16. Note that since in this mode there is no ablation, the coagulation depth increases with the fluence, as opposed to the ablative modes where coagulation depth is reduced at higher laser fluences.

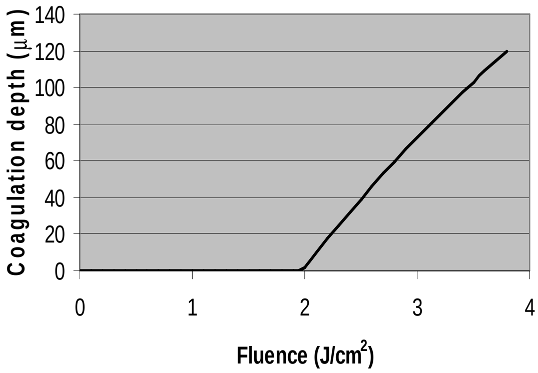


Fig. 16: Large coagulation depths without skin ablation can be achieved with the Fotona SMOOTH mode.

Histological investigations show that SMOOTH mode treatments result in collagen coagulation as deep as 300 µm below the epidermal-dermal junction. [9, 13-17, 22-23] Clinically, this collagen coagulation results in visible and long-lasting reduction of wrinkles and scars. [14, 18]

An advantage of the non-ablative SMOOTH mode treatment compared to an ablative laser treatment is that during and immediately following the SMOOTH treatment the epidermis remains intact thus protecting the skin from infection. Only in the 12–72 hours after the treatment, when recovery has already started, do the damaged superficial layers begin to peel off. SMOOTH treatment can be considered as a delayed ablative procedure. A disadvantage of the SMOOTH treatment comparing to ablative resurfacing is that the clinical results are less pronounced.

Typical laser fluence settings for SMOOTH treatments are in the 2.5 – 4 J/cm^2 range [11-24, 42]. Note that for super-long laser pulses in SMOOTH mode these fluences are below the ablation range. The heat deposition depth is a function of power settings and number of passes. Generally 1–3 passes are used. The post-op appearance of the skin is a red/brown discoloration with a sunburn sensation.

FOTONA FRACTIONAL, PIXEL SCREEN TECHNOLOGY Er:YAG TREATMENTS

To provide fractional treatments, Fotona has developed unique Pixel Screen Technology (PST) that divides the basic Er:YAG treatment beam into parallel beam pixels (see Fig. 17). The advantage of Fotona's PST compared to other fractional technologies is that it allows the laser beam quality and parameters within the pixels to remain unchanged compared to the basic beam properties. This enables the practitioner to perform all nine basic VSP Er:YAG ablative treatments and the SMOOTH treatment with fully clinically tested laser parameters. The only difference is that the skin is treated with pixelated Er:YAG laser beams. Other fractional technologies use focused beams with modified pulse fluences in the fractional spots and therefore with modified and relatively uncontrolled thermal treatment modalities. Fotona's PST ensures that the laser fluence in each pixel is exactly as it would be with a standard Er:YAG laser handpiece.

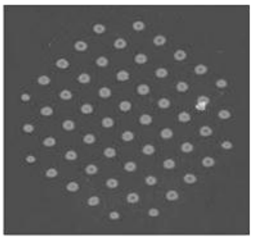


Fig. 17: A typical Fotona PST Er:YAG laser beam spot..

In what follows, we describe two Fotona PST laser handpieces; PS01, a "soft fractional" PST Er:YAG handpiece and PS02, a "sharp fractional" PST Er:YAG handpiece. Both handpieces have been designed and developed for "stamped" fractional photothemolysis techniques, as opposed to the scanning fractional technique. The latter technique requires a scanner and in some systems expensive consumables. The PS01 and PS02 handpieces are incorporated in Fotona's high-quality Titanium range of handpieces.

Fotona PS01 fractional laser handpiece

The PS01 handpiece (see Fig. 18) is a "soft fractional" handpiece. The laser fluence within each pixel gradually diminishes from the center of the pixel to its edge due to its exclusive optical solution. Transitions from the areas of high to low light intensity on the skin are therefore soft and gradual. This handpiece is especially suited for minimally ablative and non-ablative treatments at larger spotsizes (7-12 mm).

Fig. 18: The soft fractional PS01 laser handpiece.

A typical PS01 pixel beam profile is shown in Figure 19.

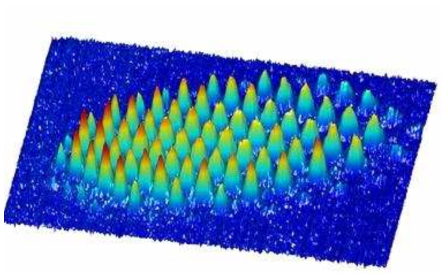


Fig. 19: A typical PS01 pixel beam profile. Note the soft laser intensity transition between the pixels.

The PS01 handpiece is also a variable handpiece that allows the operator to vary the number of pixels, the size of pixels, and the total laser spotsize. For a fixed pixel level (from 1 to 5) the number of pixels is fixed, and the pixel size and pattern can be varied by changing the laser spotsize. The number of pixels can then be additionally adjusted in the range from 75 to 7 pixels by adjusting the pixel level from 1 to 5 (see Fig. 20).

	Spot size	7mm	10mm	12mm
Pixel Level 1	Pixel No.	75	75	75
	Pixel Size (µm)	450	500	700
Pixel Level 2	Pixel No.	50	50	50
	Pixel Size (µm)	600	700	800
Pixel Level 3	Pixel No.	30	30	30
	Pixel Size (µm)	800	1000	1300
Pixel Level 4	Pixel No.	17	17	17
	Pixel Size (µm)	1100	1500	1800
Pixel Level 5	Pixel No.	7	7	7
	Pixel Size (µm)	1500 - 2000	1800 - 2300	2500 - 3000

Fig. 20: Pixel pattern possibilities for the PS01 handpiece.

Fotona PS02 fractional laser handpiece

The Fotona PS02 handpiece (see Fig. 21) is a "sharp" fractional handpiece.

Fig. 21: The sharp fractional PS02 laser handpiece.

"Sharp" signifies that the laser energy is contained within the pixels and that the laser beam quality and parameters within the pixels remain unchanged compared to the basic beam properties. With the PS02 handpiece, the practitioner can perform all nine basic VSP ablative and SMOOTH treatments at fully clinically tested laser parameters (see Fig. 22). The only difference is that the skin is treated with pixelated Er:YAG laser beams.

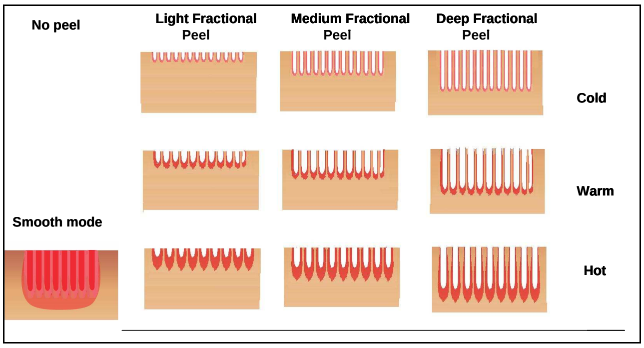


Fig. 22: The PS02 treatment regimes are in principle the same as the basic VSP Er:YAG treatment regimes, but through pixelation they are less invasive and have shorter downtimes

The PS02 handpiece generates a fixed number of 37 pixels within a laser spot. Approximately 11% nominal coverage is provided regardless of the selected spotsize (see Fig. 23). The PS02 handpiece is thus a fixed pixel-number handpiece.

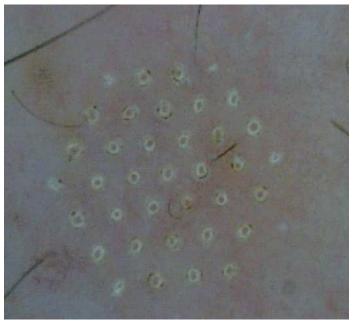


Fig. 23: The PS02 fractional pixel pattern with the 5 mm laser spotsize.

Spotsize (mm)	Pixel-size* (µm)	Distance between pixels (mm)
3	180	0.40
5	270	0.70
7	370	0.96
10	560	1.56
12	700	1.90

* Due to the physics of the ablation process typically observed sizes of the microchannels in the skin are approximately 100 µm at 3 mm, 180 µm at 5 mm and 220 µm at 7 mm spotsizes.

Fig. 24: The PS02 pixel specifications at fixed number of 37 pixels.

When very large ablation depths are desired, the ablation depth can be increased by using the so-called

TURBO mode. This mode allows the practitioner to determine the treatment depth by selecting the fluence and the number of pulses to be stacked on the same treatment area (see Fig 25). As always in ablative mode, the coagulation depth is determined by pulsewidth.

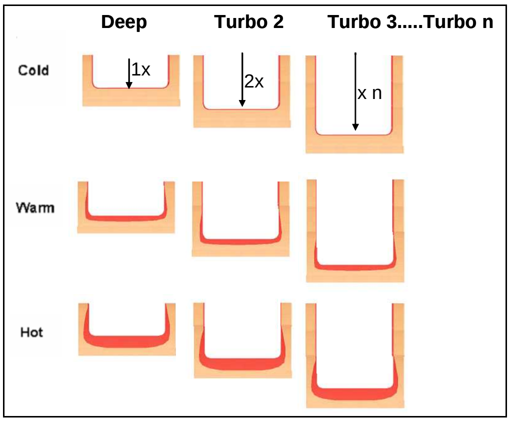


Fig. 25: The TURBO enhancement mode provides increased ablative action.

When, for example, a *cold deep peel* treatment regime is selected with the addition of the TURBO 3 modality, the ablative depth (but not the coagulative depth) will be three times larger compared to the basic *cold deep peel* treatment regime.

The Fotona TURBO mode provides VSP Er:YAG laser fractional treatments greater flexibility. It allows fractional treatments to be accomplished from the keratinous layer to depths the practitioner deems necessary for the clinical application at hand. TURBO mode can be used to reach deeper into the dermis than traditional (non-fractional) resurfacing techniques (see Fig. 26).

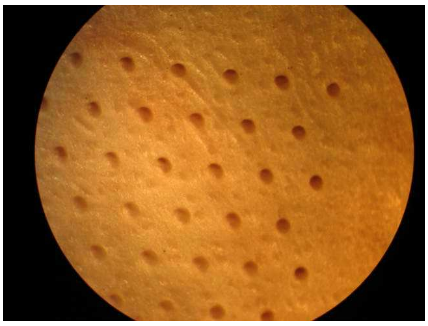


Fig. 26: Fractional TURBO ablation with the Fotona VSP Er:YAG laser.

While the TURBO fractional technique is more aggressive on the skin, the effect is counter-balanced by the fact that the skin is affected only within a smaller percentage of the fractionally treated area.

CLINICAL EXPERIENCE

Clinical observations and histological findings demonstrate that fractional ablative treatments with the Er:YAG laser are a safe and effective alternative to more aggressive full-ablation laser treatments [25,26,27, 32-37].

Typical treatment parameters for skin rejuvenation procedures are around 1-5 J/cm², in one to three passes and using a combination of varying pulsewidths. Shorter (0.2 – 0.3 ms) VSP Er:YAG pulses during the first few passes, and longer pulses (1 – 2 ms) during the last, or last few passes [32,37]. Photographic evaluations show significant improvement in skin quality (see Fig. 27) [32]. No side effects apart from transient erythema have been reported. Mild erythema was markedly reduced after 1 – 2 days, and totally disappeared after one week.

Fig. 27: Removal of Lentigo Senilis using Fotona's PST fractional ablative Er:YAG laser; before and one week after a single session (SP+LP modes, three passes). Courtesy of Dr. L. Volovec [32].

Fig. 28: Reduction of peri-ocular wrinkles using the Fotona SMOOTH Er:YAG laser; before and 60 days following a single session (three passes). Courtesy of Dr. C. Pidal [36].

For the treatment of moderate to severe rhytides (peri-oral, peri-orbital) with minimal patient downtime deeper Er:YAG fractional ablation and thicker coagulation is needed. Treatment parameters can vary from 3 J/cm² to 60 J/cm², where higher fluences are achieved in a stacked (TURBO) mode with 3-5 stacked pulses [25,26,33]. Areas are treated with several passes in one session. Substantial improvements in peri-oral and peri-orbital wrinkles have been observed with more aggressive treatments (four and more passes). In comparison to full-surface ablative skin resurfacing, the fractionated VSP Er:YAG laser treatment provides very rapid reepithelization, with limited adverse side effects (mild post-inflammatory erythema at 3 months or less depending on coagulation thickness) and reduces patient downtime to 4 days or less.

In addition, Fotona PST fractional modalities have been successfully used in the reduction of stretch marks. Significant improvements in stretch mark size, color and texture have been reported [34,35] using treatment protocols consisting of a combination of VSP Er:YAG PST fractional and non-fractional modalities [36]. Stretch mark reduction of more than 50% in a single session is achieved without any significant side effects. Mild post-inflammatory erythema disappears within 24 hours [36].

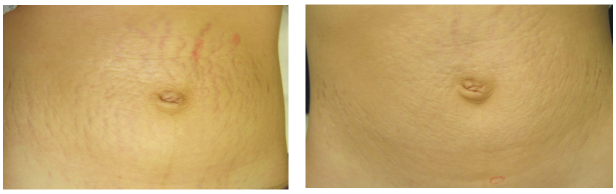


Fig. 29: Reduction of stretch marks using Fotona PST fractional ablative Er:YAG laser; before and one week after a single session. Settings used: SMOOTH mode, pixel level 2, three passes, followed by 2 passes of non-fractionated VSP mode and 2 passes SP mode. Courtesy of Dr. C. Pidal [36].

Fig. 30: Reduction of stretch marks using Fotona PST fractional ablative Er:YAG laser; before and 4 months following four sessions in a 4-week period. Settings used: SP mode, pixel level 2, one pass along the stretch mark, followed with one pass across the stretch mark, and one final pass along the stretch mark with XLP mode. Courtesy of Dr. J. Kozarev [35].

CONCLUSION

In conclusion, Er:YAG fractional photothermolysis with the Fotona PST provides an additional option in the treatment of various skin conditions, avoiding some of the adverse effects of full-ablative laser procedures while improving the limited efficacy of the non-ablative treatments.

The combination of the latest Fotona SMOOTH, PIXEL SCREEN and TURBO techniques, provides 11 basic treatment modalities (see Fig. 31) and 11 fractional treatment modalities (see Fig. 32).

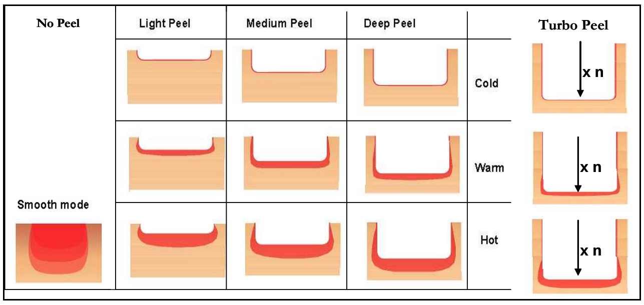


Fig. 31: 11 basic VSP Er:YAG treatment modalities.

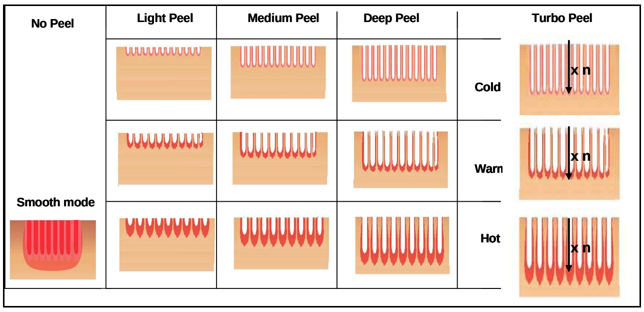


Fig. 32: 11 fractional VSP Er:YAG treatment modalities.

The advanced Fotona VSP Er:YAG technology thus enables the practitioner to adjust the laser treatment modality to the patient type and the treated indication. There is no other laser wavelength, nor technology that allows similar levels of treatment control and precision, while providing the extent of treatment modalities presented in this paper.

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