New Options and Treatment Strategies with the VSP Erbium YAG Aesthetics Lasers

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Abstract:

Er:YAG laser resurfacing has been widely recognized as an effective and predictable method to reverse the signs of photo-damage. Whereas other ablative light-technologies have not developed much further, therefore limiting their versatility and applicability, new developments and innovations to Er:YAG lasers have given practitioners a wide variety of new treatment options and strategies. In order to fully benefit from the Er:YAG lasers versatility in aesthetics it is important for the practitioner to understand and appreciate the basic biophysics and technology behind the latest VSP Er:YAG lasers. A deeper understanding of the 4 VSP Er:YAG treatment regimes (COLD, WARM, HOT, NON-ABLATIVE) gives insight into the clinical parameters that are necessary for the most common VSP Er:YAG treatments, that are mini peels, medium depth peels and SMOOTH treatments.

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

INTRODUCTION

The treatment of aged and photo-damaged skin with a variety of cutaneous resurfacing techniques has been available for many years. The majority of these procedures have become obsolete with the introduction of Er:YAG lasers. Namely, Er:YAG laser resurfacing provides an extremely safe and precise method for "feather-like" light induced "peeling" of aged or scarred skin tissue. Since the introduction of new and promising non-ablative methods, ablative skin resurfacing treatments may have lost their popularity because of their longer healing times. However, non-ablative methods are not a comparable alternative to the ablative skin resurfacing.[10-12] Non-ablative methods offer only subtle, incremental, and gradual improvements. Also, a relatively high proportion of non-respondents additionally limit the clinical success rate. For this reason, it is now generally accepted that only minimally ablative Er:YAG laser resurfacing treatments consistently produces optimum results with no comparable alternative.[1,2,21] This is especially true for Er:YAG lasers based on the latest VSP (Variable Square Pulse) technology[3] that enable the laser practitioner to operate in a completely cold ablative mode; without thermal effects in deeper-lying tissues.

While Er:YAG laser resurfacing remains the most effective and predictable method to reverse the signs of photo-damage, the latest VSP Er:YAG technology has even broadened the scope of use of the Er:YAG laser. Namely, VSP technology enables the physician to select various modes of operation, ranging from precise micron-by-micron layer, cold ablation to a combined ablative and thermal treatment, and even a completely thermal, non-ablative (SMOOTH) [4] skin rejuvenation deep in the dermis. VSP technology-based Er:YAG lasers thus provide the practitioner with the widest possible range of skin rejuvenation treatments and is for this reason becoming the golden standard tool in aesthetic clinics worldwide.

This paper discusses basic laser biophysics, clinical parameters and the technology behind the latest VSP Er:YAG aesthetic laser systems.

OPTIMAL WAVELENGTH FOR SUPERFICIAL SKIN TREATMENTS

Of all laser types, the Er:YAG laser with 2.94 μm wavelength has the highest absorption coefficient in water [Fig. 1]. Since the skin consists of 70% water, this is the most efficient wavelength for ablating skin. Due to the very high absorption in human skin, tissue structures deeper than approximately 5 μm below the skin surface are not directly heated by Er:YAG laser light. The Er:YAG laser can therefore be considered a perfect tool for treating skin surfaces. However, this does not mean that the Er:YAG laser cannot be used for treating deeper-lying skin layers. Since the amount of heat diffusion depends on laser pulse characteristics, heat from the superficial laser-tissue interaction can be allowed to diffuse deeper into the skin, by using advanced and unique technological solutions. This makes the Er:YAG laser a unique treatment tool where the depth of the tissue effect can be controlled by the practitioner solely by choosing the appropriate laser parameters.

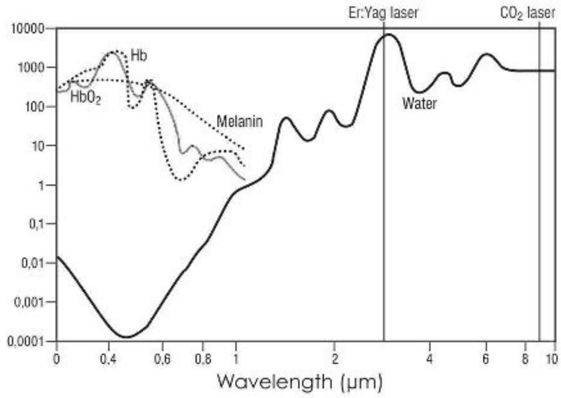

Fig. 1: The Er:YAG (2.9 µm) laser has the highest absorption in water and consequently in human skin. An alternative laser that emits in the high absorption region is the CO_2 laser (9.6 µm), however this laser is still 15 times less absorbed in water and is thus less suitable for laser resurfacing.

Practitioners have long used carbon dioxide (CO_2) laser for facial resurfacing treatments. This device can be effective for this purpose, but a considerable number of post-operative issues with this laser source have been reported. The reason lies in the 15 times lower absorption in human skin of the CO_2 laser wavelength (9.6µm) compared to the Er:YAG laser wavelength. The CO_2 laser light penetrates much deeper (approx. 100-200 µm) into the skin, which can cause deep, uncontrollable thermal damage to the deeper dermis. In addition, since a larger volume of skin needs to be heated to achieve an ablation effect, CO_2 lasers are less effective and efficient, and have a much more limited parameter range in which their use on patients can be considered safe. Er:YAG lasers have therefore almost completely replaced CO_2 lasers for skin resurfacing procedures.

PULSE SHAPE – VARIABLE SQUARE PULSE TECHNOLOGY

Er:YAG laser light 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 case a long laser pulse or continuous irradiation is applied, 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 lower ablation efficacy and 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 [Fig. 2] ; 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. Fig. 2 shows a square pulse generated with VSP technology, compared to a standard laser pulse. A significant difference between the two types of pulses is that for square pulses the average power and the peak power is 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, which ultimately leads to superior treatment outcomes, with less discomfort and fewer side effects.

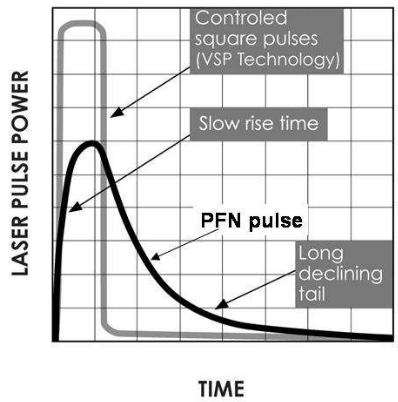

Fig. 2: Comparison between PFN and VSP shaped pulses.

An additional advantage of VSP technology is that it allows the user to easily adjust the pulsewidth and laser power, or even form a controlled train of micropulses within a larger overall pulse thereby optimizing the efficacy and safety of treatments, by making each pulse with a particular pulsewidth completely predictable from a clinical outcome point of view.

Closely related to VSP technology is EFC (Energy Feedback Control) [4] technology, which gives the laser system the ability to control the energy of individual laser pulses. Less advanced skin resurfacing devices do not measure and adjust the energy of individual laser pulses but rather rely on the initial calibration procedure when the device is switched on. However since a laser's efficiency depends on the laser temperature and its instantaneous power generating capacity, the energy of laser pulses may vary significantly during laser operation. This is especially critical in Er:YAG laser systems since Er:YAG laser efficiency drops significantly at higher laser system operating temperatures. [26-27] Fig. 3 (left) shows what a laser pulse train looks like without the intervention of Energy Feedback Control (EFC) technology; the energy level of each subsequent pulse decreases. This results in inefficient treatments, wasted time and dissatisfied patients. Fig. 3 (right) shows how a pulse train looks with EFC support. EFC measures the energy of each single laser pulse with two independent internal energy meters and adjusts the VSP parameters to keep the laser pulse energies constant. VSP technology then enables the construction of square pulses. The control of energy bursts results in the ability to vary the height and the length of a burst resulting in VSP-shaped pulses.

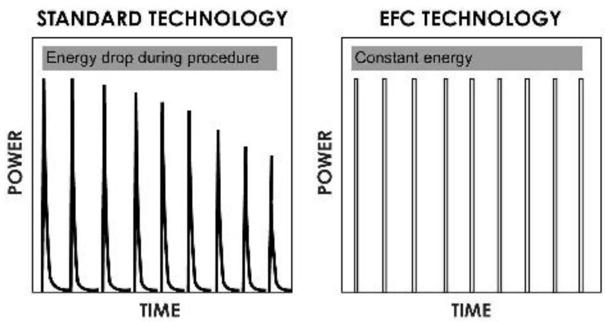

Fig. 3: Energy levels of a laser pulse train without the intervention of EFC technology (left) and with the support of EFC technology (right).

ENERGY DISTRIBUTION CONSIDERATIONS

Standard laser handpieces emit laser beams with a Gaussian profile and thus an energy distribution that resembles a conical shape [Fig. 5b]. Higher focal fluences at the centre of the spot are created, while the fluence decreases towards the edge of the spot. This type of handpiece therefore does not allow the practitioner to control the treatment regime over the whole illuminated spot area.

Fig. 4 shows that, for a selected fluence value on the laser keyboard (which is in reality only the average fluence), a 4 mm spot with the "Gaussian" handpiece will emit laser radiation in the center of the spot with a focal fluence value twice the value of the "top-hat" handpiece, and practically zero at the edges of the spot. For example, if a fluence value of 1.5 J/cm^2 is selected on the keyboard (which would be just above the threshold for skin ablation) a "Gaussian" handpiece would emit 3 J/cm^2 at the center of the spot which would result in an aggressive ablation in the center of the spot, and only a light peel at the edges of the spot.

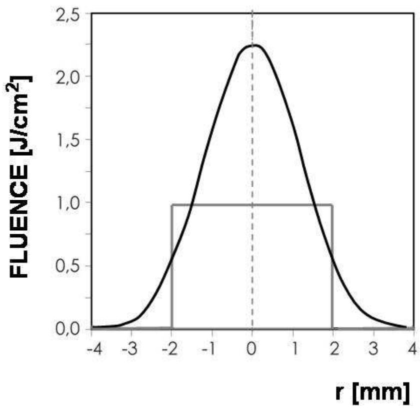

Fig. 4: Comparison of peak fluence values of Gaussian and top-hat beam profiles for the same average fluence and 4 mm spotsize.

For this reason, special *"top-hat"* profile [Fig. 5a] Er:YAG handpieces have been developed (Fotona R11 or R04). Because of their much more homogeneous beam profile, top-hat handpieces are much safer and effective compared to standard Gaussian profile handpieces.

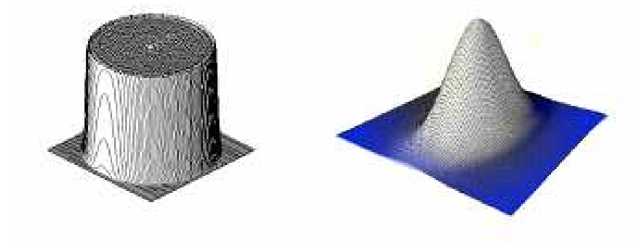

Fig. 5: A top-hat handpiece beam profile (left) and a Gaussian handpiece beam profile (right).

FOUR TREATMENT REGIMES

Recent technological advances in laser aesthetic treatments have been facilitated by equally exciting developments in the theoretical understanding of Er:YAG laser ablation of biological tissues.[6, 24]

It is now well-understood that there are four Er:YAG treatment regimes depending on the laser pulsewidth and the laser pulse energy [6] or more correctly, laser fluence (i.e. the laser energy per surface area in J/cm^2) [Fig. 6]. The more energy that is transformed into heat, the less efficient the ablative effect and the greater the skin collagen coagulation effect.

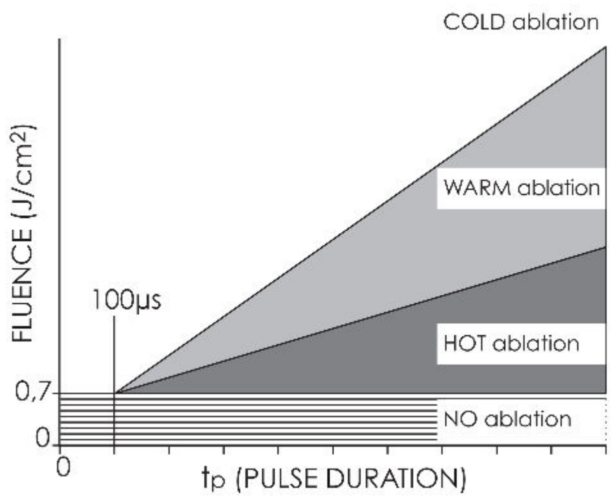

Fig. 6: Schematical overview of the four Er:YAG treatment regimes.

Fig. 6 shows that at high fluences and low pulse durations, the speed of ablation is faster than the diffusion of heat into the tissue so that all of the laser energy is used up for COLD ABLATION. With decreasing fluences and/or longer pulsewidths, the thermally affected tissue layer at the end of the pulse becomes thicker. Thermal effects become more pronounced and ablation efficiency is considerably reduced (WARM ABLATION and at even lower energies HOT ABLATION). At fluences below the ablation threshold there is NO ABLATION [Fig. 7]. [25]

Note that the values in Fig. 6 are only approximate as the exact values depend on skin type, treatment location, skin hydration levels and other parameters. The ablation threshold fluence of approximately 0.7 J/cm² can thus vary in real patient situations between 0.4 and 1.2 J/cm². Note also that the indicated boundaries between the regions of cold, warm and hot ablation only approximate and in reality more gradual transitions exist between these treatment regimes.

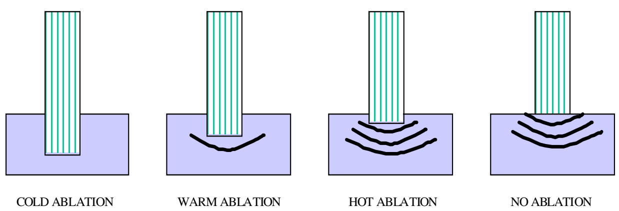

Fig.7: The effect of the VSP Er:YAG laser beam on human tissue in the four ablation regimes. Ablation efficiency is highest and thermal effects are lowest in the cold ablation regime. When the laser energy is too low or the pulse duration is too high there is no ablation and all of the energy is released in the form of heat.

Standard VSP Er:YAG single laser pulse durations are: 100 µsec (Very Short Pulse or VSP mode), 300 µsec (Short Pulse or SP mode), 600 µsec (Long Pulse or LP mode), 1000 µsec (Very Long Pulse or VLP mode), and 1500 µsec (eXtra Long Pulse or XLP mode). Additionally, SMOOTH mode is a super-long 200.000-350.000 µsec pulse.

Many practitioners might assume that in order to work more safely, laser energy should be decreased. Paradoxically, this is not always the case. If the energy settings of the laser are reduced, more thermal effects in the tissue may be created. For this reason, it is important to understand the relation between the laser pulse energy E, laser fluence F (energy per area unit) and the selected laser spotsize D:

$$F = E / (\pi D^2/4)$$

Fluence is directly proportional to the laser energy and inversely related to the spotsize area. A smaller spotsize will result in a much greater amount of fluence being applied to the skin than when using a larger spotsize with the same laser pulse energy. Table 1 shows the relationship between selected laser energy (in mJ) and the resulting laser fluence (in J/cm²) for different spotsize diameters (in mm):

D (mm)	E (mJ)						
	50	100	300	500	1000	1500	3000
2	1,59	3,18	9,55	15,92	31,85	47,77	95,54
3	0,71	1,42	4,25	7,08	14,15	21,23	42,46
4	0,40	0,80	2,39	3,98	7,96	11,94	23,89
5	0,25	0,51	1,53	2,55	5,10	7,64	15,29
6	0,18	0,35	1,06	1,77	3,54	5,31	10,62
7	0,13	0,26	0,78	1,30	2,60	3,90	7,80
8	0,10	0,20	0,60	1,00	1,99	2,99	5,97
9	0,08	0,16	0,47	0,79	1,57	2,36	4,72
10	0,06	0,13	0,38	0,64	1,27	1,91	3,82
12	0,04	0,09	0,27	0,44	0,88	1,33	2,65

Table 1: The relationship between laser fluence (in J/cm²), laser pulse energy E (in mJ) and the laser spotsize diameter D (in mm).

If a small spotsize is used, a much lower energy setting must be selected to obtain the same fluence values compared to when a larger spotsize is used. As can be seen from table 1 (above); in order to achieve a fluence higher than, e.g. 3 J/cm², an energy setting of only 100 mJ has to be used for a 2 mm spotsize, while an energy setting of 3000 mJ is required for a 10 mm spotsize. Variations in spotsize are therefore very influential when selecting treatment parameters.

At the same time the energy of the laser pulse is directly related to the fluence value applied to the skin, i.e. if the energy values are doubled, the fluence applied to the skin will double.

A. Cold Ablation Regime

The cold ablation treatment regime (upper left area in Fig. 6) is the basic treatment modality of VSP Er:YAG lasers. Ablation results from micro-explosions in a well-defined superficial layer of overheated tissue water. Almost instantaneously, heated tissue particles are ejected away from the underlying yet unheated tissue. The absolute and unique advantage of this Er:YAG regime is that there is basically no thermal damage to the remaining non-ablated tissue.[7] The absence of thermal damage results in faster re-epithelization and an improved side effect profile.

The ablation rate in the cold ablation regime is approximately 5 μm per J/cm². Each J/cm² will thus instantly vaporize approximately 5 μm of tissue, leaving minimal damage to the skin. For example, the required fluence to remove the epidermis of the eyelid (with thickness of 50-70 μm) is 10-15 J/cm² in a single pass.

Some commercial laser systems allow the user to pre-select the ablation depth for specific treatments. However, exact ablation rate and thus ablation depth depends on the skin type, location of the treated area, the level of skin hydration and other non-laser related parameters. The practitioner is therefore strongly advised not to rely on preset parameters but rather to adjust the parameters depending on the observed clinical effects.

Visual markers of depth are:

Whitish colouring of the skin after administering laser pulses generally indicates the Er:YAG laser treatment has reached the intra-epidermal level.

Yellowish colouring of the skin after administering laser pulses generally indicates the Er:YAG laser treatment has reached the intra-dermal level.

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. When the Er:YAG laser treatment is continued on the papillary dermis level, punctate bleeding will become more frequent.

The right therapeutic ablation depth is the minimum depth needed to achieve the desired clinical result, whether it is 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 punctuate bleeding appears which indicates the papillary dermis has been reached. At the level of the papillary dermis a maximum therapeutic effect is achieved with a minimum of risk of side effects. Continuing to treat any deeper than the papillary dermis, has minimal clinical effects, while the potential of complications and side effects may even exponentially increase. With experience it is advisable to select laser treatment settings that will give the desired result in 2-4 passes.

Three common cold ablation treatment regimes can be distinguished: removal of benign skin lesions, medium depth peels and VSP mini peels:

a) REMOVAL OF BENIGN SKIN LESIONS. Because several passes and/or stacking of pulses may be needed, it is important to use cold ablation settings. Treatments are performed in the VSP or SP mode with fluence settings of 1.78-5 J/cm² [Fig. 6]. Multiple passes and/or stacking of pulses are used to plane the lesion down. A short pause after every 3-5 stacked pulses lets heat dissipate. Debris is sponged off to assess results. SP mode can be used for the first 2 to 3 passes then VSP mode is used as the skin surface is reached. In this way less heat is dissipated to the area under the lesion and thus the risk of thermal necrosis in the area is significantly decreased.

b) MEDIUM DEPTH PEEL. This treatment procedure gives the best clinical outcome at the still acceptable down time of 7-10 days. The treatments are performed in the cold ablation VSP or SP mode with fluence settings of 1.7 – 5 J/ cm² as needed. At the start of the procedure consider using a 350 mJ energy setting and a 5 mm spotsize, which corresponds to a 1.78 J/ cm² fluence value. As the treatment progresses, or if no immediate results are visible, or with more clinical experience, fluence settings may be increased depending on the desired outcome.

c) VSP MINI PEEL. This treatment is described in the section below, together with other mini peel treatments.

B) Warm and Hot Ablation

In laser resurfacing, additional coagulation of collagen in the papillary dermis has been shown to lead to further skin tightening/sculpting and formation of new collagen. [7-8] The goal of warm and hot ablation treatments is to combine the effects of cold ablation with that of collagen heating in the deeper-lying non-ablated tissue.

VSP Er:YAG technology allows the practitioner to adjust the level of collagen coagulation by adjusting the fluence and pulsewidth settings. By varying the fluence settings with a fixed pulsewidth, it is possible to adjust the depth of thermal effects in a single pulse application [Fig.6]; i.e. the lower the fluence setting, the lower the ablation rate and the deeper the thermal effect. At high enough fluences where the principles of the cold ablation regime apply, thermal effects become very superficial and limited to the natural Er:YAG laser absorption depth of 5 microns. Similar effects can be achieved by varying the pulsewidth at a fixed fluence setting; i.e. the longer the pulsewidth, the deeper the thermal effect. For pulsewidths of, or below approximately 100 μsec, the thermal effect again becomes limited to the Er:YAG laser absorption depth of 5 microns. In general, longer pulsewidths and lower laser fluence settings increase the coagulative effect. However, the coagulation depths that can be achieved with a single laser pulse are limited to 30-50 μm.[9, 23]

Warm and hot ablation parameters are mainly used for MINI-PEEL laser treatments.[20] These peels are performed close to the minimum ablative setting. MINI-PEEL laser treatments actually cover the complete range of collagen heating: from the cold ablation VSP MINI-PEEL to the combined ablation and moderate heating SP MINI-PEEL, to the LP MINI-PEEL where ablation is combined with deeper heating effects.

a) VSP MINI-PEEL. This peel is used when a minimum of heat deposition is required, and is performed in the VSP mode (100 μsec pulsewidth). Fluence settings range from 0.8 to 1.2 J/cm² which for this pulsewidth lies within the cold ablation range [Fig. 6]. The fluence setting is selected in such a way that a white spot appears if less ablation is desired or a crisp white spot for more ablation. This will be in the energy range of 160 to 220 mJ for a 5 mm spotsize. Immediate post-op sensations should be minimal. A sunburn-like sensation can be reported in 1-4 hours post-op, which will pass within 12-48 hours. On average, redness will persist for 36 hours, with a maximum of 72 hours, although in many cases no redness is reported. Swelling is not seen except in the most sensitive patients.

b) SP MINI-PEEL. This peel is performed in SP mode (300 μsec pulsewidth). From Fig. 6 it can be seen that when fluence settings in the range of 0.8–1.2 J/cm² are selected, at this pulsewidth, there will be some heat deposition and collagen remodeling (warm ablation). The depth of ablation is again determined by the pulse energy (fluence). Because the pulsewidth is longer, energy settings will be slightly higher for a similar ablation depth. Visual markers of depth are the same as for the VSP mini-peel. The immediate post-op sensation is similar to sunburn, persistent for 12–72 hours. Swelling is generally not seen but is more common than after VSP mini-peels.

c) LP MINI-PEEL. This treatment is performed in LP mode (600 μsec pulsewidth) and is chosen for its significant heat production and thus higher collagen remodeling effects. The depth of the treatment is dependant of the fluence settings. The longer pulsewidth setting requires even more energy to achieve the same ablative effect. However, typical fluence settings are still in the 0.8–1.4 J/cm² range, which can achieved by selecting 160–270 mJ range settings for a 5 mm spotsize. These treatments lie within the hot ablation regime [Fig. 6]. Redness is immediate and lasts up to 5 days but is generally minimal within 4 days. Swelling that would not be noticed by the casual observer but that is felt by the patient is common. More significant swelling is seen in 20 percent of patients.

A single MINI-PEEL treatment session will provide the same results as an entire package of micro-dermabrasion treatment sessions. In addition, depending on the chosen type of peel, the MINI PEEL will deposit heat to the collagen layer and improve skin tone, texture and tightness. Note that when more collagen heating is achieved (longer pulse duration is selected), the number days of post-op redness or swelling will increase [Fig. 8]. [20]

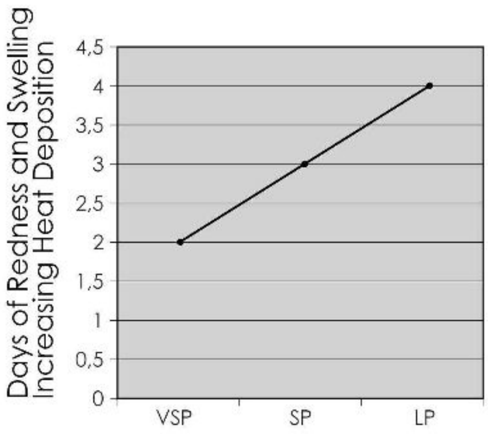

Fig. 8. Estimated number of days of post-op swelling

and redness depending on the type of MINI PEEL (VSP, SP, or LP). [20]

When bleeding needs to be controlled during a treatment, laser treatment settings that correspond to a very hot treatment regime may be used. Longer pulsewidth modes such as VLP (1000 µsec) or XLP (1500 µsec) are used with low fluence settings of 1-1.5 J/cm² [Fig. 6] and high repetition rates of 15-20 Hz. [20] Laser pulses (3-10) are stacked immediately after the blotting the area to coagulate the lesion.

C) Non-Ablative SMOOTH Regime

The VSP Er:YAG laser SMOOTH treatment modality is a specially developed non-ablative regime. 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 never reaching the temperatures required for ablation (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, and the delivered laser energy results in an overall build-up of heat and thus creates a temperature increase deep in the papillary dermis.

The above principle is employed when the VSP super-long SMOOTH pulse is used. The SMOOTH pulse delivers 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 SMOOTH super-long pulses are longer than the epidermal TRT, the conditions described in Fig. 6, no longer apply and the overall SMOOTH pulse threshold ablation fluence is much higher than 0.7 J/cm². Conditions for ablation are thus never reached.

Histological investigations have shown that SMOOTH pulse treatments result in collagen coagulation as deep as 300 µm bellow 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 a non-ablative SMOOTH pulse treatment when compared to an ablative laser treatment is that during and immediately following the SMOOTH treatment the skin epidermis remains intact thus protecting the skin from any infection. Only in 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 a delayed ablative procedure. A disadvantage of the SMOOTH treatment when compared to ablative resurfacing is that the clinical results are less pronounced.

Typical laser fluence settings for the SMOOTH treatments are in the 2.5–4 J/cm² range.[20] Note that for super-long laser pulses in SMOOTH mode these fluences are below the ablation fluence range. Depth of heat deposition 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.

COMPARISON OF ER:YAG SMOOTH TREATMENTS AND PLASMA KINETIC RESURFACING TREATMENTS

Recently, new plasma skin resurfacing (PSR) aesthetic systems have gained some interest due to their non-ablative skin resurfacing effects.[19] The technique is based on delivering pulsed hot nitrogen plasma to the skin surface that results in rapid heating of the skin surface. It is worth noting that this technique is in principle equivalent to the non-ablative Er:YAG SMOOTH mode technique. Both methods rely on rapid non-ablative heating of the skin surface only, as neither Er:YAG laser radiation nor hot nitrogen gas can penetrate deeper into the skin [Fig. 9]. Collagen coagulation is thus achieved by the same process of heat diffusion deeper into the underlying skin tissue.

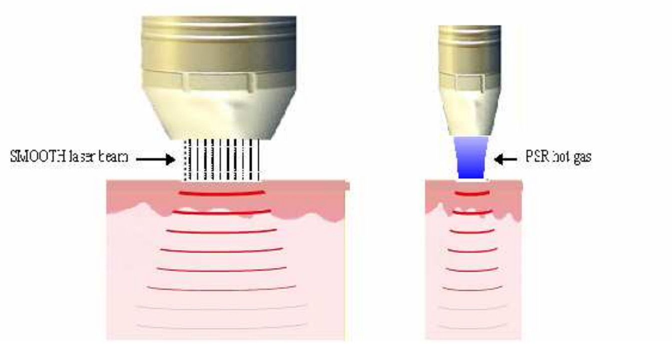

Fig. 10: Both, the laser SMOOTH and the plasma kinetic PSR technique are based on a pulsed heating of the skin surface. Heating of the deeper lying tissue is

achieved by means of heat diffusion from the heated epidermal surface.

While the Er:YAG SMOOTH and PSR techniques are basically equivalent in terms of their effect on the skin tissue there are some distinct advantages of using the Er:YAG laser systems. Firstly, the Er:YAG SMOOTH technique allows the use of much larger spotsizes (up to 12 mm in the commercially available laser systems) compared to the 3-4 mm spotsizes of the PSR. This allows much shorter treatment times especially in full face resurfacing treatments. More importantly, the PSR heating energy distribution on the skin surface is approximately Gaussian and not top-hat as is the case with VSP Er:YAG laser handpieces. This leads to non-homogeneous and poorly controlled skin resurfacing in PSR treatments, with a much higher chance of side effects. And lastly, the SMOOTH mode is just one of several skin resurfacing (ablative, combined ablative/coagulative and purely coagulative) modalities of VSP Er:YAG laser systems while PSR systems can be used only for a limited range of non-ablative coagulative treatments.

CONCLUSION

Er:YAG lasers with a 2.94 μm wavelength have the highest absorption coefficient in water and thus do not penetrate more than approx. 5 μm into the skin. This makes Er:YAG lasers a unique resurfacing treatment tool where the depth of the tissue effect can be controlled by solely choosing the appropriate laser treatment parameters. With the introduction of VSP technology that provides square-shaped laser pulses without heating surrounding tissue structures, Er:YAG laser treatments are far more predictable, which leads to superior treatment outcomes, with less discomfort and fewer side effects.

To further improve the safety of treatments it is recommended to use specially-developed “top-hat” Er:YAG handpieces that avoid peak fluences at the center of the laser spot, as is the case in less advanced Gaussian profile handpieces. Because of their much more homogeneous beam profile, top-hat handpieces are much safer and effective.

VSP Er:YAG lasers offer four treatment modalities, depending on fluence and pulsewidth settings.

In COLD ablation regimes, high fluences and short pulsewidths ensure that the speed of ablation is faster than heat diffusion into the skin. This regime is ideally suited for the removal of benign skin lesions, medium depth peels and VSP mini peels. Its unique advantage is the absence of thermal damage to the remaining non-ablated tissue, resulting in faster re-epithelization and an improved side effect profile.

WARM and HOT ablation regimes, based on longer pulsewidth and lower fluence settings, combine the effects of cold ablation with that of collagen heating in the deeper-lying non-ablated tissue for a rejuvenation effect. These regimes allow a range of mini-peel laser treatments that are performed close to the minimum ablative setting, while covering a complete range of collagen heating. A single mini-peel session will provide the same results as an entire package of micro-dermabrasion treatment sessions.

Within the NON-ABLATIVE regime lies the specially-developed SMOOTH treatment, in which laser energy is delivered onto the skin in a fast sequence of low fluence laser pulses in a super-long pulse, while never reaching the ablation threshold. Histological investigations show deep collagen coagulation resulting in long-lasting reduction of wrinkles. Due the lack of ablation, the skin remains intact after the treatment protecting the skin from infection. SMOOTH treatments are in principle similar to PSR techniques, although larger spotsizes and top-hat profile handpieces are used.

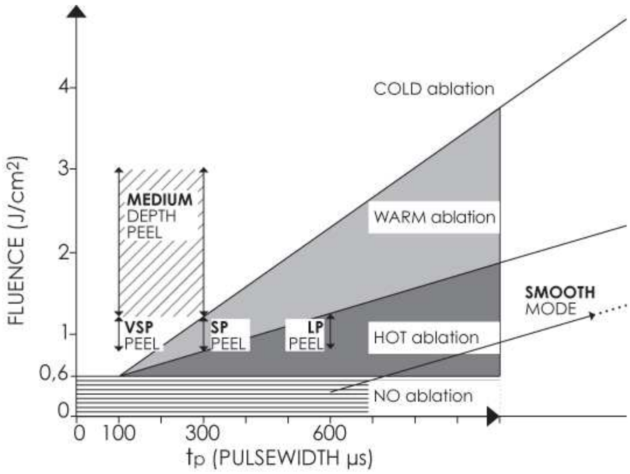

Fig. 11: The position of the most common Er:YAG laser treatments: VSP PEEL, SP PEEL, LP PEEL, MEDIUM DEPTH PEEL and SMOOTH mode on the treatment regime diagram. Note that the SMOOTH mode pulsewidth is so long that ablation does not occur even at higher overall pulse fluences, and is always in a hot non-ablative regime.

By understanding these four treatment modalities, the physician will be able to benefit greatly from the predictability and treatment precision VSP Er:YAG lasers have to offer. Resurfacing treatments can now be provided that are completely catered to the needs of the patient in terms of envisioned clinical outcome and down-time. No other resurfacing treatment modality to date can offer this degree of treatment versatility.

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3. Variable Square Pulse (VSP) is a Fotona d.d. (www.fotona.eu) proprietary technology for the generation and control of laser pulses.
4. SMOOTH is a super long Er:YAG pulse sequence available in VSP Er:YAG lasers developed by Fotona d.d..
5. Energy Feedback Control (EFC) is a Fotona d.d. (www.fotona.eu) VSP based technology for the measurement and control of individual laser pulses.
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