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Photo-Thermal Hormetic Rejuvenation with 1064 nm Nd:YAG PIANO Pulse Laser

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ABSTRACT

The purpose of this prospective pilot study was to assess the effectiveness, safety, and tolerability of a novel super-long (PIANO) Nd:YAG 1064nm laser pulse used to improve premature facial aging.

A pilot study was conducted on 16 female patients affected by premature aging. The skin of the neck was selected for our treatment. The antero-lateral neck surface was divided into three standardized segments. Each segment was exposed to a fixed number of passes, (one, two or three) The same parameters were used for each pass: 24 J/cm2 , 20 mm spot size, and 1.5 seconds super-long pulsewidth. A standardized interval of 5 minutes was chosen to separate subsequent laser passes. A total number of 6 weekly sessions was considered adequate to obtain a rejuvenating effect, similarly to most multipolar RF-dependent anti-aging tretments.. Objective skin measurements (elastometry, erythema, and melanin) were taken immediately before, 42 days after treatment initiation, and 120 days after the end of the last laser session. Overall textural improvements were assessed by two independent dermatologists and also by patients 120-days post treatment. A standardized 5-point improvement scale was used to assess the degree of clinical changes .

All subjects completed the study. Melanin increased by 0.52% (1 pass areas) and 0.86% (2 and 3 pass areas) at 42 days; 1.2% (1 pass areas) and 10.5% (2 and 3 pass areas) at 120 days. Erythema increased by 1.3% (1 pass areas) and 2.5% (2 and 3 pass areas) at 42 days; 1.6% and 4.6% after 120 days respectively. Skin elasticity improved by 7% (1 pass aeas) and 21% (2 and 3 pass areas) after 42 days; 4% and 10.8% after 120 days. Improvements were rated moderate to good on double and triple pass areas (independent observers interrated reliability was 72%). No scars were observed. Mild, transient, spot hyperpigmentation was observed in two subjects (2 and 3 pass areas) after 42 days. All subjects tolerated the laser procedures well. Patients' satisfaction was rated moderate to good on double and triple pass areas. 90% of study subjects confirmed their willingness to repeat the procedure as part of their anti-aging preventive strategy.

Our data confirmed that PIANO super-long laser pulses are safe and effective and coluld be considered as a useful non-invasive treatment option of a modern anti-aging strategy..

Key words: super-long laser pulse, PIANO pulse, laser treatment, Nd:YAG laser, hormesis

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I. INTRODUCTION

Aging processes have been intensively studied for years and are nowadays, in spite of their extreme complexity, quite well known, understood and described [1]. The human body lives thanks to a constant process of regeneration, maintenance and repair of its tissues. Aging could be interpreted as a progressive reduction of this regenerative ability. There are thousands of researchers looking for effective methods to slow down, stop or even revert aging. Many approaches have been developed and many "anti-aging" methods are already in use.

One of these approaches is based on inducing repetitive, mild thermal stress on living cells. The principle of exposing organisms to various toxins and a variety of other stressors (in our case abrupt changes of temperature) to achieve a positive cellular reaction, is known as hormesis. Hormetic rejuvenation is becoming increasingly popular thanks to its simple and safe biological approach. There are quite a lot of articles on hormetic stretegies and there is more and more evidence that repetitive mild cellular stress induces anti-aging effects [2,3]. In their recent work, Dams et al. showed that repetitive mild heat stress (45°C and 60°C for 2 seconds) is inducing anti-aging

hormetic effects on cellular metabolism, stimulating fibroblast replication and procollagen I and III synthesis [4].

There are many aesthetic procedures to reju venate the skin which are based on controlled temperature increase within tissue using various energy sources (lasers, radiofrequency, ultrasound, plasma), Lasers have become the energy source of choice due to their elevated tissue selectivity. The ability of specific laser wavelengths to induce thermal modifications of specific tissue structures is called selective photothermolysis and has been widely used in laser treatments since its original description in the early eighties [5]. Laser pulse duration is another important parameter to control photothermal effects on exposed tissue. Different outcomes can be achieved simply adjusting pulse durations to biological structures-dependent thermal relaxation times [6].

In skin rejuvenation treatments based on selective photo-thermal light-tissue interaction, one of the most important challenges is to reach deeper skin layers without damaging the epidermis. A common strategy to protect the epidermis is based on its cooling during laser irradiation. Various cooling techniques have proven effecttive in providing adequate protection. Recently another, innovative photothermal rejuvenating approach has been proposed by laser manufacturer Fotona using a super-long, seconds range, 1064nm Nd:YAG laser, the deepest penetrating wavelength among all lasers used in medicine and aesthetics. This concept treatment, named PIANO modality, takes maximum advantage of the difference between cooling times of thin epidermal layers and thick dermal tissue. When super-long pulse PIANO modality is used, temperature distribution within the skin is dominated by diffusion and not by thermal relaxation times [7]. Differences of temperature variations within the skin between a standard 20 msec. long pulse and super-long 1.5 sec. PIANO pulse are shown in Fig. 1.

The temperature spike produced within epidermis after millisecond (LP) pulses does not develop during super-long (SL PIANO) pulses because of a skin-specific heat diffusion process, which spares the epidermis from overheating.

In this pilot study we evaluated the use of this novel super-long 1064nm Nd:YAG laser pulse concept in facial skin rejuvenation matching temperatures proven effective in stimulating an hormetic cellular response causing mild thermal stresses to the treated tissue.

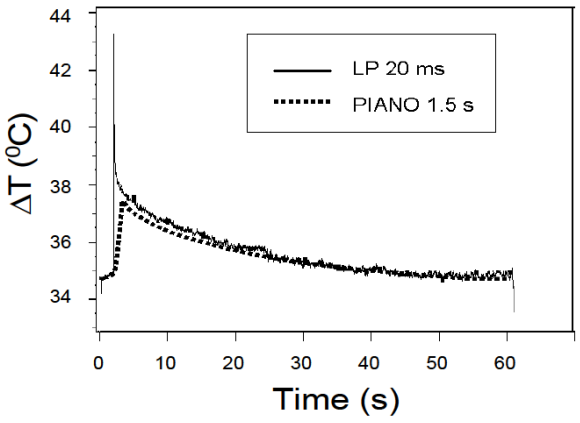

Fig. 1: Temperature surge and time distribution measured on the dorsal aspect of hands following 1064nm Nd:YAG laser irradiation according to super-long (SL) PIANO 1.5 s pulse mode (dotted line), and long pulse (LP) 20 ms pulse mode. The same pulse fluence of 35 J/cm2 was used for both pulse duration modes. Figure reprinted with permission from ref. 7.

II. MATERIALS AND METHODS

This was a prospective, internally controlled pilot study conducted at a single laser dermatology facility, the Skin Doctors' Center, in Trieste, Italy in the period between September 2011 and December 2011.

Sixteen Fitzpatrick type 2-3 subjects (age 38-45, mean 41) affected by premature aging accepted to be treated. The 1064 nm Nd:YAG laser source (SP Dynamis – Fotona, Ljubljana, Slovenia) was used for the study. Standardized treatment parameters (20 mm spot, 1.5 sec, 24 J/cm2) were used in single, double, and triple subsequent passes, with 5 min. intervals between passes, on three different neck areas (See Fig. 2).

Epidermal cooling was performed with Zimmer Cryo5 – level 2. The same facial skin care (facial cleanser + facial moisturizing cream b.i.d.) was prescribed for the full duration of the study. The treatment protocol consisted of six laser sessions (1 session per week). The treatment detail, where neck area 2 is treated with a 20 mm large spot, is presented on Fig.3. For photo-thermal hormetic rejuvenation effects, skin temperatures of 42-45°C had to be reached during the treatment (See Fig. 4).

Non-invasive objective skin measurements (elastometry, erythema, melanin) were taken immediately before, after 42 days, and 120 days after the end of the six laser sessions. All measurements were taken at standardized environmental conditions.

Standardized digital photographs (10.5 megapixel Canon EOS1000D – 50 mm macro-lens and dedicated TTL flash) were taken at the same time intervals.

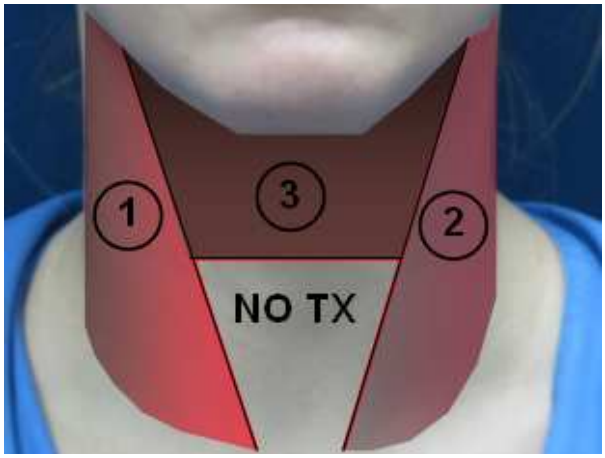

Fig. 2: Three treatment areas on the neck. Area 1 received one single pass of PIANO Nd:YAG laser irradiation, area 2 received two passes with a 5 minutes pause interval, and area 3 received three passes with the same 5 minutes pause interval after each of the passes.

Two independent observers were asked to blindly evaluate overall textural improvements at 120 days on a 5-point evaluation scale. Safety evaluation included post-treatment dyspigmentation and scarring.

Patient satisfaction was surveyed at the end of the full laser treatment by a self-assessment clinical efficacy questionnaire based on a 5-point improvement scale (1=no improvement, 2=minor improvement, 3=moderate improvement, 4=good improvement, 5=excellent improvement). Patients were also asked to describe their tolerance during and immediately after laser exposures as well as their willingness to repeat the procedure.

Fig. 3: Treatment of neck area 2 with 1.5 sec super-long pulse using 20 mm spot.

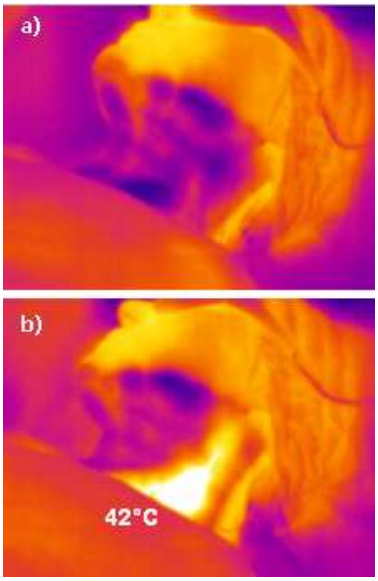

Fig. 4: Thermal pictures of the neck area 2 a) before the treatment and b) immediately after two passes of super-long Nd:YAG laser pulse irradiation. A surface skin temperature of 42°C was developed across the whole treated area.

III. RESULTS

Blind evaluation of clinical photographs by two independent dermatologists obtained a 72% concordance level. Clinical improvements were considered absent (65%) to minor (35%) on single laser pass treated sites, and moderate (70%) to good (30%) on double and triple laser pass treated sites (See Fig.5). Erythema increased by 1.3% on single pass areas and 2.5% in double and triple pass areas after 42 days; 1.6% and 4.6% after 120 days. Melanin increased by 0.52% in single pass and 0.86% in double and triple pass areas after 42 days; 1.2% and 10.5% after 120 days.

Elastometry readings improved by 7% on single pass areas and 21% on double and triple pass areas after 42 days; 4% and 10.8% after 120 days (See Fig. 6). No scars were observed (See Fig. 7). Mild, transient spot hyperpigmentation was observed in two subjects on 2 and 3 pass areas. Alterations resolved spontaneously after 120 days. 1064 nm laser treatment was considered ineffective on single pass areas by 90% of subjects after 120 days; improvements were rated moderate (75%) to good (25%) on double and triple pass areas (See Fig. 8). All subjects tolerated the laser procedures well. The majority of subjects (90%) confirmed their willingness to repeat their laser treatments (two and three laser passes) as part of a personalized anti-aging prevention and maintenance regime.

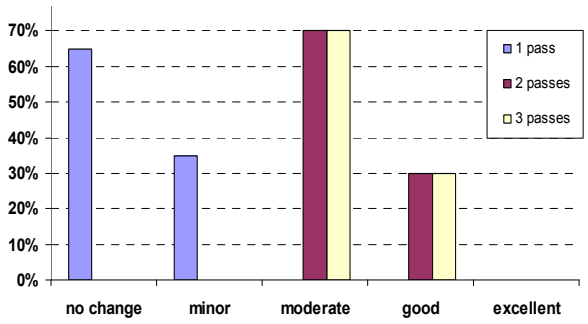

Fig. 5: Overall clinical improvement assessed by two independent professional observers. While single pass treatment didn't show much improvement, double and triple passes resulted in moderate-to-good improvements.

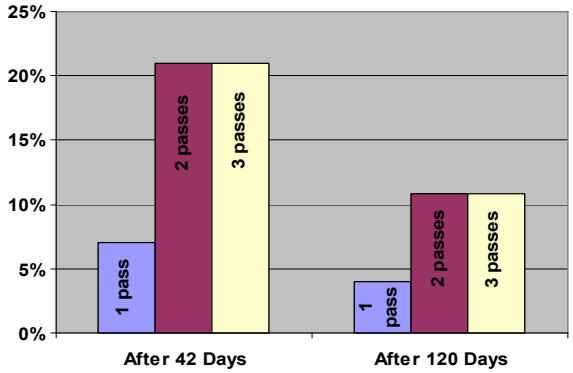

Fig. 6: Improvement in elasticity following the PIANO treatment, depending on the number of passes.

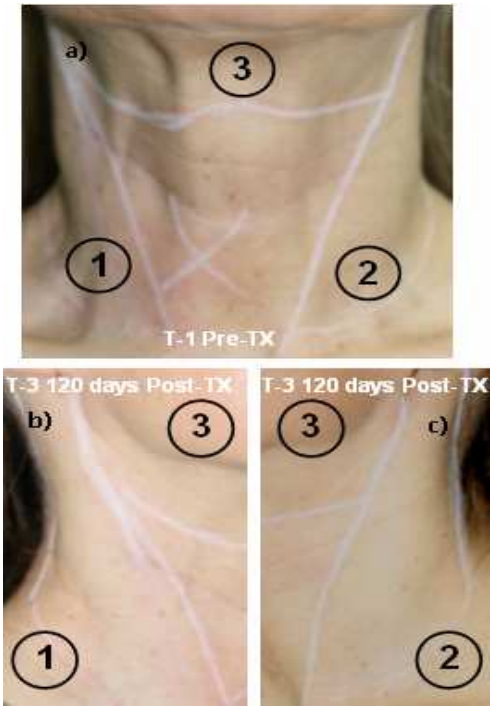

Fig. 7: Example of the neck a) before the treatment with super-long Nd:YAG laser pulse, and b) and c) at 120 days after the treatment. Three areas receiving different amounts of laser energy (1, 2 or 3 passes) are clearly marked.

Fig. 8: Patients' overall skin improvement subjectively perceived 120 days after the last laser session. The majority of single laser pass areas (90%) were perceived as unchanged, while all patients noticed a moderate-to-good improvement within areas exposed to two and three laser passes

IV. DISCUSSION

Non-ablative photo-thermal skin rejuvenation using Nd:YAG 1064 nm lasers is currently used by many laser practitioners all around the world. This treatment modality is supported by a large base of clinical studies [8-18]. Nd:YAG 1064 nm lasers have gained popularity in skin rejuvenation procedures due to their unique tissue interactions. 1064nm stays within the so called "optical window" of the skin and is the deepest penetrating wavelength enabling to reach even the lowest dermal layers and the subdermal fatty tissue. Its laser's core robustness is able to support a wide range of working conditions, delivering large amounts of power within a various useful pulse durations. This specific laser wavelenght has demonstrated to be an excellent tool to effectively induce collagen contraction and remodeling as well as stimulate neocollagenesis, an essential step in skin rejuvenation. [9, 14, 16].

So far most non-ablative Nd:YAG 1064 nm laser-assisted skin rejuvenation procedures [8-13] were performed using so-called long pulse settings within millisecond range (usually 5-to-50 msec). Some practitioners have successfully used shorter, sub-millisecond pulses to obtain evident clinical improvements. [14-17], particularly when dealing with darker phototype skin. A few years ago we reported the clinical effectiveness of a scanner-assisted combined treatment where both long pulse and sub-millisecond pulse modalities were seguently used during the same laser session [18]. However in all of these procedures epidermal temperatures higher than 45°C are usually reached bringing up concerns about potential damage to epidermis. In order to minimize unnecessary thermally-related epidermal damage, some

authors [11] suggested to use relatively low fluences in a repetitive way (irradiating the same skin area with several passes) slowly increasing the skin temperature up to 42-45°. This range of temperatures are still safe for the epidermis and high enough for collagen remodeling in treated areas.

The new super-long PIANO pulse was designed to achieve a volumetric heating of the dermis while sparing the epidermis from unnecessary thermal damage [7].

In this pilot study we used a "3 split neck" method with the aim of identifying the minimal effective super long pulse photothermal parameters of laser irradiation which would result in clinically evident skin rejuvenation, keeping patient pain tolerability within acceptable levels.

Our results showed that a single pass of super-long 1064nm Nd:YAG pulses with selected parameters was not able to deliver a sufficient amount of heat to induce noticeable changes in overall skin appearance, even if superficial skin temperature achieved the desired 42°C corresponding to a dermal temperature of roughly 45-47 C. Results on the other two neck segments (2 and 3), treated with double and triple passes showed consistent skin improvements and also quite comparable results, indicating that two passes are sufficient for such a minimally invasive rejuvenating procedure and that it is possible to shorten the treatment time by omitting the third pass.

All patients tolerated the treatment quite well and expressed a high level of willingness to repeat the procedure when positive clinical effects fade away. Except for a short-term, mild and transient spot hyperpigmentation observed in two subjects on the 2- and 3-passes areas, there where no other adverse effects, including blistering, textural changes, and scarring.

V. CONCLUSIONS

Super-long 1064nm laser PIANO pulse photo-thermal cutaneous treatment was able to produce encouraging clinical results when double or triple subsequent passes were performed. Further studies are under way to identify the ideal treatment parameters to safely and effectively rejuvenate the skin with this innovative, highly promising technology.

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