High Power Q-Switched Nd:YAG 1,064-nm Fractional Laser for Non-Ablative Skin Remodeling

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ABSTRACT

Introduction. Q-switched lasers are often used for tattoo removal and other applications which demand high laser intensities in nanosecond pulses. Interestingly, the Q-switched 1064-nm neodymium:YAG (Nd:YAG) laser was the first non-ablative laser clinically tested over a decade ago. Recently, a new generation of these lasers featuring higher power and fractionated beams have been introduced for non-ablative skin remodeling and rejuvenation. The purpose of this report is to summarize the initial clinical experience with this new High Power Q-Switched Nd:YAG 1,064-nm Fractional Laser.

Material & Methods. The Pixel® QSW module (Harmony®XL platform) is a fractional Q-switched 1064-nm Nd:YAG handpiece with a passive refractive optical element that creates a 5x5 matrix with 25 microscopic holes (~200μm in diameter /each) and high power density per pixel (60-130J/cm^2). The repetition rate of the laser can be adjusted to 1, 2 or 5Hz. Treatment was performed on sixty patients (58 female and 2 male; age range 31-83; mean age 49.63; Fitzpatrick skin type I-VI) at the Rejuvenate Clinic in Perth, Australia between June 2010 – March 2011. Patients were randomly assigned for 3 treatments performed each week. Follow-ups were done 1 week, 3 months and 6 months after the last treatment.

Results. Significant clinical improvement was observed in most treated areas 1 week and 3 months after the last treatment. The degree of clinical improvement was found to be in most patients clinically significant.

Conclusion. The Pixel QSW offers a painless and comfortable procedure that doesn't require pre-treatment or post-treatment care. The treatment is very safe for all Fitzpatrick skin types (I-VI).

INTRODUCTION

Fractional lasers thermally alter only a small volume of the target tissue, hence avoiding complete destruction of both the epidermal and dermal compartments. Consequently, fractional selective photothermolysis has become the "gold-standard" modality in non-ablative and ablative laser applications for the treatment of multiple skin imperfections such as acne scars, surgical, atrophic and hypopigmented scars, melasma, lentigines, poikiloderma of civatte and dyspigmentation. The fractional non-ablative technique uses near-to-mid-infrared range lasers. The aim with a fractional non-ablative laser is to deliver a controlled dermal wound without harming the overlying epidermis so that all stages of wound healing and skin remodeling occur under the biologic protection of an intact epidermis (1,2).

Long pulse 1,064nm Nd:YAG lasers have been used non-ablatively, both alone and in combination with other lasers, for improvement in wrinkles, along with mild skin tightening. However, the clinical results were considered modest at best, and were associated with patient discomfort due to pain.

By contrast, short-pulse Q-switched 1,064 nm Nd:YAG lasers are often used in applications that demand high laser intensities in nanosecond pulses; such as tattoo removal (3). Interestingly, it was the first non-ablative laser clinically tested more than a decade ago for the treatment of rhytides (4).

TECHNOLOGY

The new Pixel QSW module is a fractional, high power, short pulse, 1,064nm Nd:YAG laser used with the Harmony^{XL} platform (Alma Lasers Ltd., Caesarea, Israel). Since the Q-Switched 1,064-nm wavelength laser beam is only modestly absorbed in melanin and hemoglobin, it enables deep penetration to the papillary and reticular dermis. The laser beam is fractionated by a passive refractive optical element, creating a 5x5 matrix of 25 microscopic holes (~200μm in diameter) and distributed within a 5mm x 5mm footprint (Figure 1).

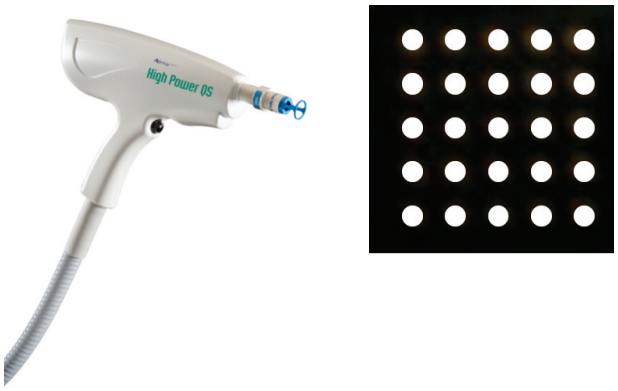

Figure 1. *High Power Pixel QSW Nd:YAG 1064-nm laser hand piece and its 5x5 pixel matrix on a 0.5 x 0.5 cm footprint.*

The PixelQSW creates high power density of each pixel (range 60 – 130J/cm^2) to facilitate non-specific thermal injury of the dermal milieu, which is believed to promote collagen remodeling – albeit with short pulse duration in the nanosecond range. The energy settings range between 400-12000 mJ/P. The pulse repetition rate of the Pixel QSW is adjustable - 1 Hz, 2 Hz or 5 Hz.

PATIENTS & METHODS

This is a prospective study of sixty patients (58 female and 2 male; age range 31-83; average 49.63±7.4; Fitzpatrick skin type I-VI) who visited the Rejuvenate Clinic between June 2010 and March 2011. Patients were randomly assigned to the Pixel QSW for correction of photoaging skin-related imperfections including fine lines, rhytides and skin laxity etc. Treatments were done on the face, arm, neck and jowl areas. Patients were given an explanation of the risks, benefits, and potential complications, and written informed consents were obtained from each patient. Table 1 depicts patient demographic and treatment characteristics.

Table 1: Patient demographics.

Demographic Criteria	No. of Patients (n = 60)
Gender F/M	58/2
Age range	35-64
Treatment Area (n)	
Face*	432
Neck	6
Forearms	6
Jowls	6
Skin Types (n)	
I	2
II	35
III	10
IV	10
V	2
VI	1

**Face= forehead; glabellar; upper lids; lowe lids; crow's feet; Naso-labial folds; mentolabial folds; smokers-line*

PROTOCOL

Face & neck protocol: The laser tip was kept in contact with the patient's skin throughout the procedure. The treatment was done on dry skin without any conductive medium between the laser and the skin. Three treatments were done every week on the entire face & neck for three consecutive weeks at the following settings: week 1 - 600mJ/P at 1Hz; week 2 - 700mJ/P at 1Hz; week 3 - 800mJ/P at 1Hz. Passes: One pass was done on the entire face; 2 passes for target areas. Average pulses per face were about 350 pulses. No visible clinical end points were noticeable on the skin except slight skin warmth sensation upon palpation.

No preoperative preparation was required. Prior to treatment, the skin was cleaned and any makeup was removed. No topical anesthesia or other analgesia means were used in any patients.

Post-treatment care included only sun protection lotion. Patients were followed up 1 week, 3 and 6 months (on-going) after the last treatment. High resolution photography (Sony DSC T300, Japan) was taken before and 1 week after the last treatment. No adverse side effects or down-time for any of the patients was documented.

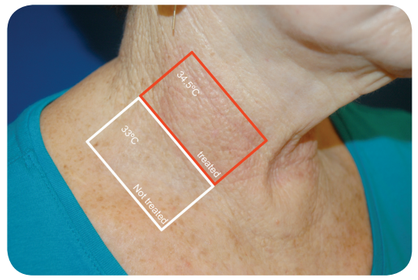

Figure 2. *Treatment end-points after 1000mJ/P at 5Hz; Upper red rectangle showing erythema, skin warmth 1.5-2 degrees centigrade vs no treatment area (lower white rectangle).*

RESULTS

The procedure on all patients was found to be pain-free and safe for all Fitzpatrick skin types (I-VI). Patient clinical outcome was evaluated with high resolution before and after photography by 2 independent photo-raters. Score of improvement was rated according to the following scale: I =no improvement (0%); II=minor improvement (<25%); III moderate improvement (26-50%); IV=marked improvement (51-75%); V=very significant improvement (76-100%). Table 2 depicts patient results before and 3 months after the last treatment for 10 different areas (total of 450 areas) such as the forehead, lower lids, glabela and crow's feet areas for a total of 432 treated areas on the face and 6 areas on the neck, forearm and jowls. Fifteen percent of the patients have demonstrated very significant clinical improvement (76%-100%) and approximately 22% of the patients have demonstrated improvement rates between 51-75%. In the upper and lower-lids area, 54% of the patients treated have demonstrated marked-to-very significant improvement (>51%-100%). The arm area showed the lowest clinical score with 66% of the patients (n=6) having showed no-to-mild improvement.

Table 2. Percentage of patient improvement (color scale) by treatment area, 3 months post treatment.

Score /Area	I	II	III	IV	V
Forehead	16	28	35	13	8
Upper-lids	8	12	26	30	24
Lowe-lids	10	16	20	28	26
Glabela	27	28	12	8	8
Crows-feet	12	14	27	30	17
Nasolabial	11	25	25	22	17
Mentolabial	13	16	27	29	15
Jowls*	22	18	22	20	18
Neck*	15	22	28	23	12
Arm*	29	37	15	13	6
Average	16	22	24	22	15

[* n=6]

0 % <25% 26-50% 51-75% 76-100%

DISCUSSION

This is the first reported clinical experience with a short pulse fractional Q-switched 1064-nm Nd:YAG laser for non-ablative skin remodeling and rejuvenation. The accumulated clinical results and evidence from the past six months demonstrates that the Pixel QSW ameliorated the signs of photoaged skin irregularities. Significant improvement was seen for superficial rhytides in the supra-orbital and nasolabial areas (with less noticeable changes in the glabella and smokers-line), three months and six months after only three serial treatment sessions for most of the patients. Some degree of variation in the clinical outcome can be expected, depending on patient age, skin type, degree of pre-existing photo-damage/age, smoking history and genetics. It might be that older patients with a higher degree of photo-damaged skin responded poorly in comparison with younger patients.

Typically, photo-damaged skin ground substances can histological and microscopically be identified at 300-400µm below the epidermis. Current research in laser-induced tissue damage and remodeling has focused on the extracellular matrix or collateral tissue. This remodeling involves an initial inflammatory phase characterized by massively high levels of the enzymes matrix metalloproteinases (MMPs), which degrade the fragmented collagenous matrix followed by substantial and extended production of new undamaged collagen. Fibroblasts in both photo damaged and chronologically aged human skin possess substantial capacity to produce new collagen when removed from their fragmented extracellular matrix. That being said, histologic (H&E) evidence performed after laser tissue irradiations indicates that collagen fragmentation is responsible for loss of structural integrity and impairment of fibroblast function in aged human skin. Thus, for age-related wrinkle or skin laxity improvement, the Pixel QSW 1,064-nm wavelength and its high power density energy at each pixel and penetration (~2mm) is ideal to induce, non-invasively, cascade of wound healing reaction.

The Pixel QSW is thought to stimulate new collagen production by producing a micro-thermal injury to the dermis that initiates a wound healing response. This micro-thermal injury-induced fibroblastic proliferation and apparent up-regulation of collagen expression (neocollagenesis /remodeling) leads to a thicker dermis. During wound healing, pro-collagen and type III collagen fibers with a small diameter are initially produced. Later, thicker type I collagen fibers are made and cross linking occurs, leading to an increase in the average diameter of collagen fibers in the dermis. A decrease in collagen fiber diameter has been associated with production of new collagen, which is thought to increase skin firmness and improve skin texture in patients after treatment.

Heat shock protein (HSP70) has been suggested to play a significant role in ablative and non-ablative thermal laser interventions, as well as during wound healing (6). Interestingly, non-ablative thermal laser intervention with a 1540-nm Er-glass laser resulted in a uniform up-regulation of HSP70 protein expression in the epidermal layers immediately (about 60 min) after laser procedure, with maximal expression one to three days post-intervention (7).

The skin's sub-dermal layer and the underlying collagen-containing tissue are heated without substantially modifying the melanocytes and other epithelial cells in the epidermis. The result is a contraction of the collagen tissue and a tightening of the skin. Controlled thermal injury may result in tissue shrinkage followed by an inflammatory response accompanied by the migration of fibroblasts into the area. The area is reinforced with additional connective tissue deposits as part of the tissue repair and healing phase, which is followed by a period of maturation of the newly deposited connective tissue, thereby resulting in contracture and tightening of the injured tissues and the tissue overlying dermis-epidermis interface. This newly deposited connective tissue matrix may be used to strengthen the old skin.

Historically, the Q-switched 1064-nm Nd:YAG laser has been used successfully to effect non-ablative dermal remodeling, despite its epidermis injury, pigment specificity and relative lack of absorption by water-containing tissue. Its relatively long wavelength is able to penetrate tissue depths sufficient for papillary dermal wounding, while its brief (nano-second) pulse duration limits thermal diffusion.

The Q-switched Nd:YAG laser was the first laser used as a non-ablative tool for skin rejuvenation. In their study, Goldberg and Withworth (5) compared the Q-switched Nd:YAG laser with the SilkTouch CO_2 laser and the UltraPulse CO_2 laser. The CO_2 lasers demonstrated improvement in all patients. In 3 of 11 patients the Q-switched Nd:YAG laser produced results that were indistinguishable from those of the CO_2 lasers. In six patients, clinical improvement was noted with the Q-switched Nd:YAG laser, but this was not as marked as with the pulsed CO_2 lasers. In two patients, no improvement with the Q-switched Nd:YAG laser was noted. The adverse effects from the use of the Nd:YAG laser were pinpoint bleeding and transient arythemas. Re-epithelialzation lasted an average of 3-5 days.

An improvement in the grade of wrinkles or the skin texture and elasticity by use of the Q-switched Nd:YAG laser was also cited in two additional studies by Goldberg et al., (4) which reported about 97% improvement of wrinkles that were classified at least as "slight"; the investigators in the second study stated that there was clinical improvement in thytides in six of eight patients which qualified at least as "fair".

CONCLUSION

The clinical findings suggests that the Pixel QSW 1,064-nm Nd:YAG laser is a safe and effective non-ablative instrument for all skin types for the purpose of improving photo-aging skin imperfections. Furthermore, this procedure requires no preoperative or post-operative care and is painless. The noticeable improvement is believed to be consistent with collagen structural changes related to wound healing such as collagenase, type I collagen and platelet derived growth factor with the end result of dermal remodeling.

REFRENCES

1. Menaker GM, Wrone DA, Williams RM, Moy RL. Treatment of facial rhytids with a non-ablative laser: a clinical and histologic study. Dermatol. Surg. 1999; 25: 440–444.
2. Bedi VP, Chan KF, Sink RK, Hantash BM, Herron GS, Rahman Z, Struck SK, Zachary CB. The effects of pulse energy variations on the dimensions of microscopic thermal treatment zones in non-ablative fractional resurfacing. Lasers Surg. Med. 2007; 39: 145–155.
3. Sumian CC, Pitre FB, Gauthier BE, Bouclier M, Mordon SR. Laser skin resurfacing using a frequency doubled Nd:YAG laser after topical application of an exogenous chromophore. Lasers Surg Med 1999;25:43-50.
4. Goldberg D, Metzler C. Skin resurfacing utilizing a low fluence Nd:YAG laser. J Cutan Laser Ther. 1999;1:23-27.
5. Goldberg DJ, Whitworth J. Laser skin resurfacing with the Q-switched Nd:YAG laser. Dermatol Surg. 1997;23:903-907.
6. Wilmink, GJ et al . Molecular imaging-assisted optimization of hsp70 expression during laser-induced thermal pre-conditioning for wound repair enhancement J. Invest. Dermatol. 2009; 129(1) 205–216.
7. Helbig D, Moebius A, Simon JC, Paasch U. Nonoablative skin rejuvenation devices and the role of hear shock protein 70: Results of a human skin explant model. J Biomed Opt. 2010 May-Jun;15(3):038002.

CLINICAL EVIDENCE

Before and 3 months after 3 treatments

Before and 3 months after 3 treatments

Before and 3 months after 3 treatments

Photos courtesy by:
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