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REVIEW

Clinical Results in Thermolytic and Sub-Thermolytic Q-Switched Nd:YAG Skin Rejuvenation

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ABSTRACT

Thermolytic and sub-thermolytic Q-Switched Nd:YAG treatment are able to rejuvenate the skin safely and effectively. It is more and more common for practioners (especially in Asia) to use Q-Switched Nd:YAG laser on indications other than pigmented lesions and tattoos, which are the application areas in which Nd:YAG has traditionally been used. Recent clinical results in Q-Switched Nd:YAG skin rejuvenation are reviewed.

Key words: q-switched Nd:YAG lasers, skin rejuvenation, subthermolytic, non-ablative

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I. INTRODUCTION

Q-Switched Nd:YAG lasers operate by generating intense light, the duration of which is on the order of nano-seconds. Most systems generate pulse lengths between 5-6 ns. 1064 nm light is generate by Nd:YAG lasers. The 1064 nm wavelength interacts with chromophores which are darkly colored (such as pigments and blood) and tends to pass through other chromophores. This allows it to pass under the surface of the skin, unlike ablative wavelengths like CO2 and Er:YAG.

Therefore, Q-Switched Nd:YAG lasers are able to selectively target very small structures (on account of the nanosecond length pulses they produce) with a high degree of specificity (on account of the 1064 nm wavelength they produce). This has made them the standard of care in the targeting of pigments, both natural and man-made, which have been introduced into the epidermis and dermis. Q-Switched Nd:YAG lasers are also able to target naturally occuring non-homogeneities in the skin as chromophores, this is what makes them useful in skin rejuvenation.

II. THEORY

The mechanism of action of nano-second length Nd:YAG lasers is different from the mechanism of action of longer pulsewidth Nd:YAG lasers (0.1 ms and above).

During a long laser pulse some of the energy delivered by the pulse dissipates as heat to the areas surrounding the target before the pulse completes. In some therapeutic contexts this heating can be very useful; it can stimulate collagen growth and skin healing, thereby rejuvenating the skin. However, above a certain threshold of energy delivery long laser pulses can thermally damage the skin. Below this threshold Nd:YAG lasers have been shown to increase the production of collagen I [1] and to have various benificial effects for the treatment of rhytides and other common photodamage [2]

During a nano-second laser pulse the energy delivered to the tissue does not have time to diffuse into the surroundings, but remains wholely and completely concentrated in the target. Above a certain energy threshold (approximately 5 J/cm2) Q-Switched Nd:YAG pulses have a thermolytic effect which causes the target structure to explode, sending shockwaves through the surrounding tissue. Skin tissue is not thermally but physically damaged by nano-second Nd:YAG pulses. The body's mechanisms of healing this damage lead to the expression of increased amounts of collagen III and general skin rejuvenation [1]. When Q-Switched Nd:YAG laser pulses are delivered which are below the thermolytic threshold of damage they can still have therapeutic effects. Some authors [3] have theorized that, at sub-thermolytic fluences, nano-second Nd:YAG light is still absorbed in pigments and irregularities and shatters them, however the strength of the effect is not powerful enough to produce the shockwaves seen at thermolytic fluences; therefore they have termed this effect sub-cellular selective photothermolysis.

In general, the effects seen from thermolytic treatments are similar to those seen with classical laser ablative modalities, such as Er:YAG and CO2, and the

side effects are smaller. At sub-thermolytic fluences the effects tend to be less pronounced but there is usually a complete absence of downtime whereas with thermolytic or ablative modalities, the downtime can be significant.

III. CLINICAL STUDIES

a) Thermolytic Q-Switched Treatment

Some of the first studies which investigated the efficacy of Q-switched Nd:YAG for facial rejuvenation compared it with more traditional laser wavelength to determine whether it could produce similar results. Goldberg and co-workers compared thermolytic Q-switched Nd:YAG resurfacing to CO2 resurfacing and found that the effects could be similar but usually were not as pronounced as those obtained with CO2 [4]. They used 5.5 J/cm^2 at a 3 mm spotsize and treated to a clinical endpoint of pinpoint bleeding. They noted that the recovery times were shorter in the case of Q-Switched Nd:YAG. Re-epithelialization took 3-5 days.

Cisernos et. al. also evaluated a thermolytic Q-Switched treatment for the rejuvenation of photo-aged skin and the treatment of acne scarred patients [5]. A fluence of 6-7 J/cm^2 was used for the 1064 nm wavelength; they also used a frequency doubled Q-switched Nd:YAG (which produces Q-switched light at 532 nm), which the operated at 3.5 J/cm^2, to treat acne scarring. Both treatments were found to be effective.

A histological analysis of skin 3 month after a thermolytic Q-Switched treatment was performed in 6 subjects with skin types II-IV to determine the mid-term effects of therapy. Each patient was underwent treatment at 7 J/cm^2 with a 3 mm spotsize for photo-damaged skin. Histological analysis determined that the treated area exhibited a mildly thickened upper papillary collagen zone, with an improvement in the organization of collagen fibrils in 4 of the 6 patients. Interestingly, 2 of 6 patients exhibited no visible changes. There was no scarring and no pigmentary changes occurred [6].

b) Sub-Thermolytic Q-Switched Treatment

Sub-Thermolytic Q-Switched treatment is safe and effective for the treatment of acne scarring, is only mildly painful, and has long lasting effects [7]. A study by Friedman et. al. demonstrated a significant decrease in skin roughness. The skin improvements lasted 6 months (the limit of follow-up for this study). In addition, most of the improvement occurred within the first 3 months after laser treatment as there was no significant improvement between the 3 and 6 month follow-up appointments. In this study 11 patients (phototypes I-III) were assessed for their improvement in acne scarring 1, 3, and 6 months after 5 treatments of 1064 nm QS laser. During each treatment the parameters used were 3.4 J/cm^2, 6-mm spot-size, 4 to 6 ns pulse duration, and a repetition rate of 10 Hz. No dyspigmentation or scarring was seen in these patients. The only side effects were transient erythema, and pinpoint petechia. 2 of the 11 patients required topical anesthesia.

There are many different ways of delivering Q-switched energy to the skin. In a proof-of-principle study Yaghami evaluated whether spreading the energy of one sub-thermolytic pulse between two smaller sub-thermolytic pulses could lead to improved patient outcomes [8]. Yagahmi evaluated 3 different sub-thermolytic methods of Q-switched treatments which were delivered across 6 bi-weekly treatment sessions: A single pulse delivered at 3.2 J/cm^2, 10 Hz, 6 mm spotsize, with 2-3 passes per treatment, A double pulse with the same amount of fluence (3.2 J/cm^2) split over two pulses less then 0.3 ms apart (i.e. 1.6 J/cm^2 per pulse), and A double pulse methodology in which each pulse was less then 0.3 ms a part in which the cumulative fluence was 5.7 J/cm^2 (i.e. 2.85 J/cm^2 per pulse). Interestingly, the only statistically significant differences between these three regimes was found in the patients perception of pain (and even here it was difficult to tell whether this difference was real as Yagahmi evaluated the single pulse regime against the 2 double pulse regimes grouped together). There was no significant difference in the efficacy between the single pulse and double pulse regimes. All of the treatments were found to be effective with 87% of patients showing a greater than 25% improvement, which is very good for a non-ablative treatment. There were no serious side effects, among the most frequent side effects included erythema (which effected 86% of patients) and mild edema which effected 8% of patients.

c) Sub-thermolytic Q-switched therapy in combination with Carbon Cream

This adverse effect is especially prominent when treating patients for melasma but can also occur when performing facial rejuvenation [3]. A study by Lee and co-workers evaluated the effects of Q-Switched facial rejuvenation in 24 Asian females of phototype III to V [9]. This study was a split face study which compared treatment with carbon cream to treatment without carbon cream (10% graphite, 90% mineral oil). Treatments were performed across 4 sessions at 4 week intervals. A eutectic mixture of lidocain and

prilocaine was applied under occlusion for 30 minutes. The topical carbon solution was applied for 10 minutes to ensure good penetration. The laser parameters used in this study were 1,064 nm, 6 mm spotsize, fluence of 3.5 J/cm^2. Treatment consisted of 3 to 5 passes unless the endpoint of pinpoint bleeding occurred first.

The treatment showed improvement across a number of different endpoints. Patient self evaluation after four treatment sessions indicated a 15% improvement in skin texture, a greater than 20% improvement in pore size, and an improvement of 15% in skin tone. Doctor evaluation indicated a 25% improvement in skin texture, a 35% improvement in pore size, greater than 20% improvement in skin tone at the same 4 week time point. The results indicated that there was no difference or insignificant difference between the results obtained on the non-carbon cream and on the carbon cream side. No hyper pigmentation was seen in this study, and the only side effects were mild transient erythema and petechia. The authors believe that success may be related to the achievement of pinpoint bleeding.

Surprisingly few studies have been performed on combination treatments of Q-switched laser therapy and other treatments modalities, despite the popularity of combination treatments in general. A recent study by Wattanakrai and co-workers attempted to determine whether combining an Nd:YAG laser operating at long-pulse *FRAC3*® parameters with a Q-switched laser and carbon cream could yield better results then a laser operating at *FRAC3*® parameters alone [10]. The study followed a split-face design in which one side was treated with long pulse light only and the other was treated with long pulse Q-Switched light plus carbon photoenhancer lotion. This study enrolled 22 women (phototypes III to IV) with enlarged facial pores.

The *FRAC3*® treatment side was treated with the following parameters: 0.3 ms pulse length, 21 J/cm^2, 3 mm spotsize, 7-8 Hz, with 2500-3000 shots delivered across half of the entire face. The combination side was treated first with 1500-2000 long pulse *FRAC3*® laser pulses (0.3 ms, fluence 10-14 J/cm^2, spotsize 4 mm, repetition rate 7-8 Hz). Then carbon lotion was applied and allowed to diffuse into the skin for ten minutes; following this it was wiped off of the surface of the skin, so that it only remained in the pores. Then Q-switched lasers light (6 ns pulse, fluence 1-1.5 J/cm^2, spotsize 8 mm, repetition rate 7-8 Hz) was used in a rapid circular motion until all of the carbon had been removed. 5 laser treatments were performed on each side, with 2 week intervals between each treatment and 5 treatments total.

Patients were evaluated at three follow-up sessions 4, 8 and 12 weeks after the last treatment. The decrease in pore count on the combination side was 35.5% on the Frac3 side alone the decrease was 32.9%. The improvement was significant, the difference was not. All in all there were 17 adverse side effects reported on the combination side and only 2 on the long pulse side, however the authors acknowledge that this was due to the use of an especially itchy carbon cream, which irritated the skin of the patients. This carbon cream was responsible for 12 of the adverse side effects. However, even when the events due to the itchy cream are removed there will still more adverse events (5) on the combination side then the non-combination side (2). Some of these side effects are attributable to the use of Q-switched Nd:YAG light and included 3 instances of erythema which lasted more than 24 hours, and 1 instance of hypopigmentation. A skin lightening effect also occurred and persisted during the treatment regime but disappeared quickly during follow up.

Based on the fact that there was little difference between the treatment regimes the authors concluded that there was no benefit in using this combination.

IV. CONCLUSION

Sub-Thermolytic Q-switched therapy can be used safely and effectively to rejuvenation photoaged skin, although the results will not be as dramatic as those seen with traditional ablative laser technologies (i.e. Er:YAG). Investigators found between 20 and 35% improvement over a wide range of endpoints, including pore-size reduction, skin tone, and skin texture. Acne scarring can also be successfully treated with this modality.

When performing sub-thermolytic Q-switched Nd:YAG rejuvenation investigators usually perform 4 treatments or more and use fluences between 1.5-3.5 J/cm^2. Multiple passes per treatment are the norm. Topical anesthesia may be used but is usually unnecessary.

It does not appear that carbon-cream enhances treatment, either alone, or in combination with a FRAC3 treatment. Though it also does not appear to hurt, giving results that are identical to treatments performed without carbon cream.

The side effects of sub-thermo sub-thermolytic Q-switched Nd:YAG therapy are generally mild and transient. Erythema occurs frequently but resolves without sequela. Hypopigmentation can occur. The effects of prolonged treatment are not well understood. A case series review conducted by Chan [3] of dispigmentation following sub-thermolytic Q-

switched Nd:YAG treatment found that some practitioners treated their patients with up to 50 treatments of this type of therapy. The effects of this are unknown; the same report cautions that upon the occurrence of hypopigmentation treatment should be immediately discontinued.

Hypopigmentation was not a problem in any of the studies which were reviewed. However, when the same or similar sub-thermolytic treatments are applied to melasma the occurrence of hypopigmentation is of great concern, and usually investigators must combine laser treatment with hydroquinone based topical treatments to ensure that this adverse event does not occur (and that melasma itself does not reoccur). Many of these same studies show that a positive side effect of sub-thermolytic Q-switched is an improvement of skin tone and texture, thereby confirming the results of this study.

The growing popularity of sub-thermolytic Q-switched skin rejuvenation is a circumstantial indicator of the value patients and practitioners see in this therapy. Although the results are much smaller then those seen in fully ablative laser therapies the lack of a recovery period seems to make up for this shortcoming.

The studies reviewed in this paper show that sub-thermolytic Q-switched laser therapy can be a safe and effective way to perform skin rejuvenation even on high phototype skin patients.

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