Effectiveness of short-pulse width Nd:YAG in laser hair reduction

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Summary

Introduction: Laser hair reduction (LHR) is a safe and effective way of reducing unwanted hairs over body. Long-pulse Nd:YAG laser has over the years, been proven to be particularly safe and effective in darker skin types. While conventionally, long-pulse Nd:YAG laser has been used, recently short-pulse width Nd:YAG laser of 0.6-1.6 ms which is 10-50 times less than the standard method (long-pulse) of Nd:YAG LHR, has become available.

Objectives: To study the effectiveness of short-pulse width Nd:YAG laser in LHR in Indian patients.

Material and methods: This was a prospective observational study conducted over a period of 1 year. Fifty female patients with Fitzpatrick skin type 3-5 were included. Patients underwent four sessions of LHR, with an interval of 6 weeks and then follow up was done for 6 months after the last session.

Results: The mean age of patient was 29.92 years ranging from 17 to 48 years. After finishing four sessions of LHR procedure 58%, 34%, 6%, and 2% of the patients showed excellent, good, moderate, and poor improvement respectively. No complications were seen during the treatment and after follow-up. Statistical analysis by paired t test showed the results to be statistically significant.

Conclusion: Hair reduction using unique short-pulse width Nd:YAG laser is easy to use, safe, and effective in Indian skin.

KEYWORDS laser hair reduction, Nd:YAG laser, short-pulse width

1 INTRODUCTION

Excess facial hairs as a result of hirsuitism or unwanted facial hairs both are very distressing for patient resulting in negative impact on psychological aspect and quality of life.1-2 Laser hair reduction (LHR) is a safe and effective way of reducing unwanted hairs over body.3-8

Laser hair reduction is defined as reduction in the number of terminal hairs after a given treatment, which is stable for a period of time longer than the complete growth cycle of hair follicles at the given body site.9 LHR works on the principle of selective photothermolysis where the laser light is delivered to target melanin and damage the hair follicle without damaging skin.10,11 The various systems available for LHR are ruby (694 nm) laser, alexandrite (755 nm) laser, diode (810 nm) laser, neodymium: yttrium-aluminum-garnet (Nd:YAG; 1064 nm) laser, and intense pulsed light (IPL) system. In particular Nd:YAG laser has been useful in darker skin because of its safety with respect to epidermal burn and ability to penetrate deep because of its longer wavelength.

According to the theory of selective photothermolysis, to cause damage to the hair follicle, pulse width of laser should be equal or less than the TRT of hair follicle (10-100 ms), and to spare the
epidermis pulse width should be more than TRT of the epidermis (3-10 ms).\textsuperscript{9} Fluence should be used according to the tolerance of patient and can be increased session by session. Highest tolerated fluence yields better outcome and it is determined by development of perifollicular erythema and edema which is desired, considered as an end point and a sign of optimum fluence.\textsuperscript{12,13}

In keeping with the above values of TRT, in the standard long-pulse Nd:YAG method of LHR, the pulse width used ranges from 15 to 70 ms depending on thickness of hairs and response to the treatment.\textsuperscript{9} It is effective, safe, but often causes pain. Recently studies have shown that pulse width of 0.6-1.6 ms which is 10-50 times less than the standard pulse width of Nd:YAG laser in long-pulse mode is also effective and is less painful.\textsuperscript{14,15} However, there has been little published data for laser hair removal with short-pulse Nd:YAG laser in Indian literature. Hence, we conducted this study using Nd:YAG laser pulse width of 0.6-1.6 ms to determine the effectiveness of short-pulse width Nd:YAG laser in LHR and to study the intensity of pain during LHR procedure in Indian patients.

2 | METHODS

This was a prospective observational study conducted over a period of 1 year. Fifty female patients with Fitzpatrick skin type 3-5, seeking unwanted hair removal on face were included in the study. A detailed history of every patient was taken before starting the procedure. Patients who have undergone laser hair reduction or any other hair reduction treatment recently, patients not ready for regular follow up, those with history of photosensitivity, those with any active skin disease over face, unrealistic expectation and pregnant women were excluded from the study. After proper consent the area to be treated was marked with white pencil, hairs were trimmed with motorized trimmer and the skin surface was allowed to become cool for 5 minutes prior to the procedure. Skin surface cooling before, during and after the procedure was achieved with the help of Zimmer air cooler. All the patients were advised to use sunscreen regularly and daily after procedure.

Patients underwent LHR procedure over various body sites which included face (chin, side locks, cheek and upper lip; 29 patients), upper lip (11 patients), and chin with upper neck (10 patients). Patients underwent a minimum of four sessions of LHR, each after 6 weeks and then follow-up was done for 6 months. Patients were treated with Nd:YAG laser system (Fotona XP Dynamic laser system, Slovenia) and following parameters were used depending on thickness and type of hairs,

- Spot size—6 mm (top hat beam)
- Pulse width—0.6-1.6 ms (short-pulse width)
- Pulse frequency—2-4 Hz
- Fluence—25-35 J/cm²

The fotona Nd:YAG laser has a feature of variable square pulse (VSP) with fractional laser beam. In VSP the average power and peak power remain the same throughout the set pulse width compared to the pulse forming network (PFN) used by most of the lasers, where pulse have slow rise time and relative long decline time. On exposure to short-pulse width laser beam the hairs shaft becomes completely singed and pop out suggesting hair damage due to development of peak power.

2.1 | Efficacy and safety assessment

After taking written informed consent from each patient digital photographs of treatment site were taken prior to each treatment with standardized photography settings. Hair reduction was assessed by comparing a series of digital photographs taken at each visit by study coordinator (a doctor who was not involved in the study). Photographs for assessment were taken with focus on a particular area of treatment site in each session of LHR. Thus separate photographs were taken of chin, cheeks, side locks, upper lip, and upper neck in patients who came for full face LHR. Cheek area was referred to the area below the line drawn from lower border of ear lobe to outer canthus of eye. Upper lip and chin have their own well defined specific anatomical sites and hence are easy to assess using pre- and postprocedural photographs. These area-specific photographs helped the study coordinator to compare particular area at each visit and to assess improvement. Improvement or hair reduction in terms of percentage was graded as poor (0%-25%), moderate (26%-50%), good (51%-75%), and excellent (76%-100%).

Efficacy of short-pulse Nd:YAG laser was determined by comparing the percentage of improvement after each session with the percentage of improvement after 6 weeks of fourth session. So, three groups were made for comparison of improvement after each session with improvement after 6 weeks of last session. Statistical analysis was done by applying paired t test and test of significance was taken to be $P < 0.05$.

Postprocedural severity of pain was quantified on a visual analogue scale (VAS) ranging from 0 (as no pain) to 10 (as intolerable pain). Adverse effects were evaluated by physical examination and self-report by the patient during each visit. Patient satisfaction was recorded on linear analogue scale ranging from 0 (no satisfaction) to 10 (extremely satisfied).

3 | RESULTS

Fifty patients were included in the study. Out of these fifty patients, eight patients had polycystic ovarian disease and six patients were on oral isotretinoin. The mean age of patient was 29.92 years ranging from 17 to 48 years with most (62%) of the patients were in 19-30 years age group (Table 1). Out of 50 patients 76% and 24% of the patients had Fitzpatrick skin type 4 and 5 respectively, 88% and 12% of the patients had dark, coarse hairs and brown, thin hairs respectively.

The short-pulse width which we have used in LHR has shown development of high power indicated by whitish and completely singed hair shaft just after exposure to laser beam (Figure 1). After completion of four sessions of LHR procedure, 58% and 34% of the patients showed excellent and good improvement respectively.
(Figures 2–6; Table 2) suggesting that 92% of the patients showed more than 50% improvement in hair reduction over face. 6% and 2% of the patients showed moderate and poor improvement respectively. Improvement in hair reduction after each session was statistically significant with P value of 0.00 (Paired t test; Table 3).

No complications were seen during the four sessions and the follow-up period, except transient perifollicular erythema and edema.

**TABLE 1** Table showing age distribution

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Age (years)</th>
<th>Number of patients</th>
<th>Percentage</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>&lt;18</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>19-30</td>
<td>31</td>
<td>62</td>
</tr>
<tr>
<td>3</td>
<td>&gt;30</td>
<td>16</td>
<td>32</td>
</tr>
<tr>
<td>Total</td>
<td></td>
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<td>100</td>
</tr>
<tr>
<td>Mean ± SD</td>
<td></td>
<td>29.92 ± 6.8</td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td></td>
<td>17-48 y</td>
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**FIGURE 1** Photographs (A) before and (B) just after the procedure showing whitish, completely singed hair shaft

**FIGURE 2** Comparative images showing good improvement on cheek area after four sessions of LHR

4 | DISCUSSION

Long-pulse Nd:YAG laser has been generally been found to be effective and safe in Indian skin type. However, complications like blistering, postinflammatory hyperpigmentation/hypopigmentation, and perifollicular edema and erythema, though rare, have been reported in skin type IV and V.11,16,17 Our study shows that a new pulse width (with 0.6-1.6 ms), short-pulse width Nd Yag laser is also safe and effective in causing hair reduction.

Use of short-pulse Nd:YAG laser was effective, with 92% showing good or excellent results after four sessions. Patient satisfaction was high and pain was minimal. Previous published data on the use of short-pulse width Nd yag laser have been few and limited. Fourrier et al15 used a 3.5 ms Ndyag laser and reported significant reduction in hair counts; 60% at 1 month (P < 0.001) and 24% at 3 months (P < 0.05) for optimal fluence (25-80 J/cm²), compared with 31% and 0% on the control sites; values similar to those published for Nd:YAG or diode lasers. Another study by Khatri et al18 used a 0.65 ms Nd:YAG laser and reported a 75%-100% reduction in hair count with high fluence (36 J/cm²) and 50%-75% reduction using low fluence (21 J/cm²). Similarly Danielle giambrone et al19 used a 0.65 ms Nd:YAG laser and reported a minimum of 50% of hair reduction in all patients, with 85% of patient satisfaction in an average of six treatments at 4-week intervals.

Efficacy of this short-pulse width Nd yag laser has raised interesting questions about the possible mechanism of action. LHR works on the basis of theory of selective photothermolysis, which suggest that to prevent epidermal damage the pulse width of laser should be more than the TRT of epidermis (0.1-10 ms) so that heat will diffuse to the surrounding area without retention and without damaging...
Similarly to damage the hair follicle, the pulse width of laser should be equal to or less than the TRT of hair follicle (10-100 ms) so that the heat will retain inside the hair follicle and causes its damage. Hence, this reported efficacy of short-pulse Nd:YAG laser is contrary to the above mentioned basic concept of thermal relaxation time as pulse width is far less. Since the pulse width used is far less than the TRT of both the hair and skin, it is important to explain its mechanism in LHR. The probable explanations for effectiveness of short-pulse width in LHR are as follows:

1. **Peak power**—It is the power delivered during individual laser pulse; in another words peak power is energy delivered per unit of time. This “unit of time” is nothing but pulse width of laser.

$$\text{Power} = \frac{\text{Energy}}{\text{Unit of time (pulse width)}}$$

From the above equation it is clear that if we keep energy and spot size (that is fluence) constant then the power is inversely proportional to the pulse width, which means with decrease in pulse width there will be increase in power. So here we have used pulse width 10-50 times less than the standard Nd:YAG laser pulse width which explains the development of peak power. Laser pulse with peak power is thought to target and damage hair follicle effectively and in addition to this it may also affect bulge area by heat diffusion which results in marked improvement in hair reduction. In fact, after exposure to short-pulse width Nd:YAG laser, the hair shaft appears

**FIGURE 3** Photographs showing excellent improvement on cheek area after four sessions of LHR

**FIGURE 4** Photographs showing excellent improvement on upper lip area after four sessions of LHR over upper lips
singed suggesting building up of peak power and damage to the shaft.

2. **Vascular damage**—It is also considered that peak power developed with short-pulse width may also target and damage blood vessels surrounding the hair follicle which affects hair growth. Additionally the longer wavelength (1064 nm) penetrates deeper which makes it easier to target blood vessels surrounding the hair follicle.²⁰

3. **Heat diffusion**—Although in LHR the laser beam has to be absorbed by melanin in hair follicle for selective damage, the actual hair reduction occurs by nonselective damage of bulge area and outer root sheath of hair follicle by diffusion of heat.
from the target hair follicle. This can be usually achieved by setting proper pulse width and fluence which usually needs multiple sessions of procedures depending upon type of hairs. Therefore it is considered that heat diffusion with short pulse can be achieved easily as the range of pulse width (0.6-1.6 ms) and fluence (25-35 J/cm²) used is very small which makes it easy to use appropriate parameter.

4. Nd:YAG has longer wavelength which is poorly absorbed by melanin and can penetrate deeper. This along with good surface cooling prevents development of epidermal adverse effects with the peak power by short-pulse Nd:YAG laser.

It is also notable that very few Nd:YAG laser systems are available with such a short-pulse width option and it is only recently that the short-pulse Nd:YAG laser has evoked interest. It has been used in other indications such as treatment of onychomycosis, scar treatment, and facial telangiectasias.21-23 However there is no such study available in Indian literature and our study is possibly the first study using this device in Indian skin. Further studies with larger sample size and comparison with long-pulse Nd:YAG laser are needed.

5 | CONCLUSION

Hair reduction using unique short-pulse width Nd:YAG laser is easy to use, safe, and effective in Indian skin if used with proper surface cooling. No serious adverse effects were reported by patients.

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