Evaluation of the duration of impairment of hair regrowth using different pulse widths of long pulsed Nd-YAG laser

Thesis

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ABSTRACT

Background:

A variety of lasers can be used for laser-assisted hair removal. These range from shorter-wavelength lasers like ruby (694 nm) to longer wavelengths like Nd:YAG (1,064 nm). The target chromophore for all these laser systems is follicular melanin. Melanin content in both hair and epidermis varies widely across skin types. In darker skin types, there is an increased risk of epidermal damage due to absorption of energy by the melanin in epidermis. This increased epidermal melanin also reduces the energy absorption by follicular melanin. This energy absorption may be reduced by using lasers with longer wavelengths like the Nd:YAG laser.

Aim of work:

The aim of this study is to evaluate the effect of increasing the pulse duration using different fluences on the efficacy of long-pulsed Nd-YAG laser in impairment of hair regrowth.

Patients and methods:

Thirty female patients with hirsutism were involved in this prospective clinical trial (80% of them with skin type IV and 20% with skin type III). The chin area of each patient was divided into three areas. Area (A) as the control area at the right side of the patient was treated by the classic parameters of the device. Areas (B) & (C) at the left side of the same patient received higher pulse duration while area C received high fluence. The treatment sessions were performed at one month interval for four consecutive months. Clinical evaluation and follow up were done every two weeks.

Results:

In our study the face side which was treated by a pulse duration of 50 msec, fluence 40 J/cm (left A) achieved marked improvement regarding hair reduction count in 45.83% of the patients. Yet there was no statistically significant difference between this side and the others (right side, left side B).

At the end of the study (after four laser sessions) the average mean of hair reduction was 68.5375 % which indicates the efficacy of long pulsed Nd:YAG laser in hair removal.

Both together (image analysis and the modified trichogram) showed more hair impairment with longer pulse duration on the left side.

Conclusion:

Our conclusion is that the use of long pulsed Nd:YAG can be considered as a safe and effective device for hair removal. Increasing the pulse duration significantly decreases the hair thickness and inducing telogen in the treated hairs but not the hair count. We therefore recommended that increasing the pulse duration is one of the important manipulations in the parameters required to increase the efficacy of longer hair depilation.

Key words: Nd:YAG, laser, hair removal

INTRODUCTION AND BACKGROUND

The field of laser technology has seen major advancements in the last decade, particularly in the area of laser-assisted hair removal. With the advent of longer wavelengths, longer pulse durations the currently available laser machines can now be used safely for all skin phototypes ***(Mittal et al., 2008)***.

The goal of laser photoepilation is to produce long-term, or permanent, cosmetically significant hair removal. The major proposed mechanism of action is "selective photothermolysis," with follicular melanin as the major target chromophore ***(Sadick et al., 2000)***.

This principle predicts that selective thermal damage of a pigmented target structure will result when sufficient fluence at a certain wavelength, preferentially absorbed by the target, is delivered during a time equal to or less than the thermal relaxation time of the target ***(Alai, 2009)***.

A modified theory of selective photothermolysis is used to describe the mechanism of laser hair removal because the melanocytic chromophore target as well as the amelanotic (hair follicle and stem cell) target must both be destroyed to accomplish permanent hair reduction. To achieve this goal, the longer pulse durations are used, allowing heat propagation to the entire hair follicle ***(Battle, 2011).***

The Nd:YAG laser devices hold the most prominent position among all available laser sources due to its long wavelength of 1064 nm which in terms of absorption lies in an optical window that allows light at this wavelength to penetrate deep into the skin, while its absorption in the hair follicle is strong enough to destroy hair follicles. The advantages of the long pulsed Nd-YAG lasers are the appropriate wavelength with low absorption in epidermis and deep penetration down to the hair follicles and the possibility to treat all skin types by sparing the epidermis ***(Grad et al., 2007)***.

The long-pulse Nd:YAG laser is an effective and safe method for long lasting hair removal in all skin types. The delay in hair regrowth most likely explains patient satisfaction ***(Lévy et al., 2001)***.

RATIONALE OF THE WORK

Different pulse widths are used in laser hair depilation, the long pulsed Nd-YAG laser is effective and safe method for long lasting hair removal in all skin types but no controlled studies were performed to compare the hair growth impairment achieved by each in the same patient at two different sides on the face (split chin area).

AIM OF THE WORK

The aim of this study is to evaluate the effect of increasing the pulse duration using different fluences on the efficacy of long-pulsed Nd-YAG laser in hair depilation.

CHAPTER I: Nd-YAG LASER PHYSICS

General laser physics

Historic Perspective View

LASER stands for Light Amplification by Stimulated Emission of radiation. As regards to the spectrum, laser light lies between infrared and ultraviolet light, mainly in the visible spectrum. Therefore its application does not produce new generations of iatrogenic malignancies as in case of ionizing radiation ***(Stratigos and Dover, 2000).***

In 1917, the theoretical concept of laser light was first proposed by **Albert Einstein** who published the principles of stimulated emission of radiation as part of his quantum theory. In 1955, **Townes** and **Gordon** were the first to amplify radiant energy through stimulated emission. They used ammonia gas as an optical medium to generate coherent microwave radiant energy from a device known as MASER, which stands for Microwave Amplification by Stimulated Emission of Radiation. In 1960, Ruby laser was the first true operational laser system developed by **Maiman**. He was able to generate a beam of coherent red light by stimulating a ruby crystal with microwave energy. The second device was the helium-neon (He-Ne) laser that was developed in 1961 and also in the same year, the Neodymium:Yttrium-Aluminum-Garnet (Nd:YAG) laser was developed. In 1962, the Argon laser was developed by **Bennett** followed by the Carbon dioxide (CO_2) laser in 1964 by **Patle** ***(Acland and Barlow, 2000).***

Some terms are important to be understood in laser physics and laser tissue interaction; *energy* is the capacity to do work and is measured in Joules (J), *power* is the rate at which energy is expanded and is measured in Watts (W) i.e. Joules per seconds (J/sec), and *fluence* represents the amount of energy per amount of skin surface and is expressed in Joules per centimeter square (J/cm_2) ***(Stratigos and Dover, 2000).***

LASER LIGHT PROPERTIES

Laser light has several unique properties that distinguish it from other types of light such as sunlight. These properties are; *monochromicity* in which laser light contains a single wave length or a very narrow band of wave lengths **(Fig. 1)**. The importance of this property in laser light is its ability to be selectively absorbed by specific chromophores such as melanin or hemoglobin, *coherence* means that laser radiation waves travel virtually parallel with a minimal degree of divergence. This is in contrast to the light deriving from electrical source where the beams diverge significantly **(Fig. 2)**, and *collimation(low divergence)* which means the ability of the laser beam to not spread significantly with distance, that waves have a high ordered pattern allowing the beam to be propagated across long distance without spreading and to be focused on a small spot with very high power density ***(Herd et al., 1999).***

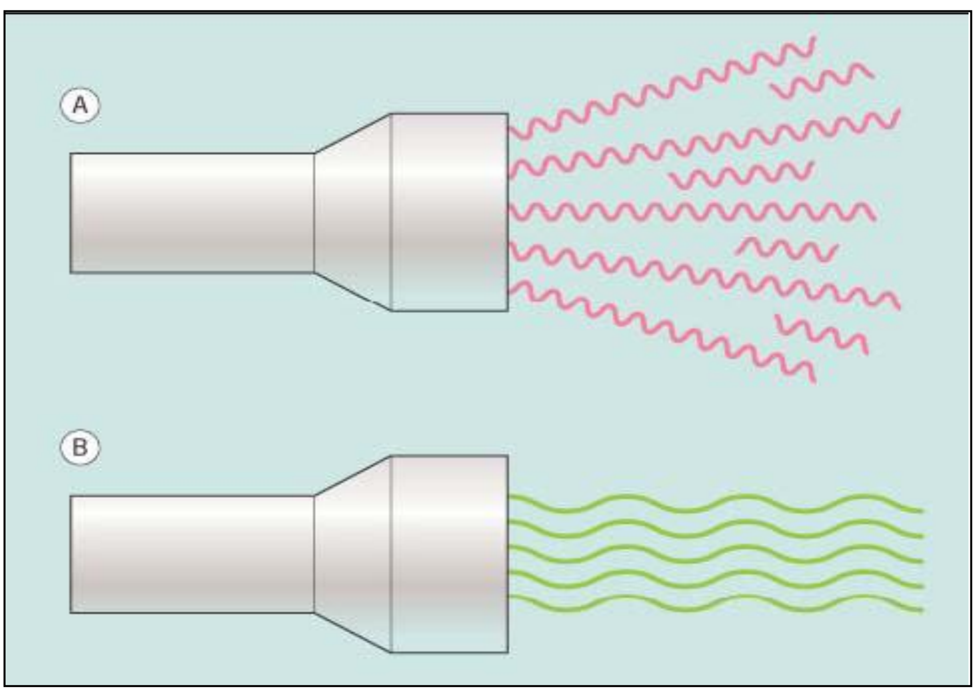

Figure 1: A. Flash light, while B. Laser light ***(Hirsch et al., 2008).***

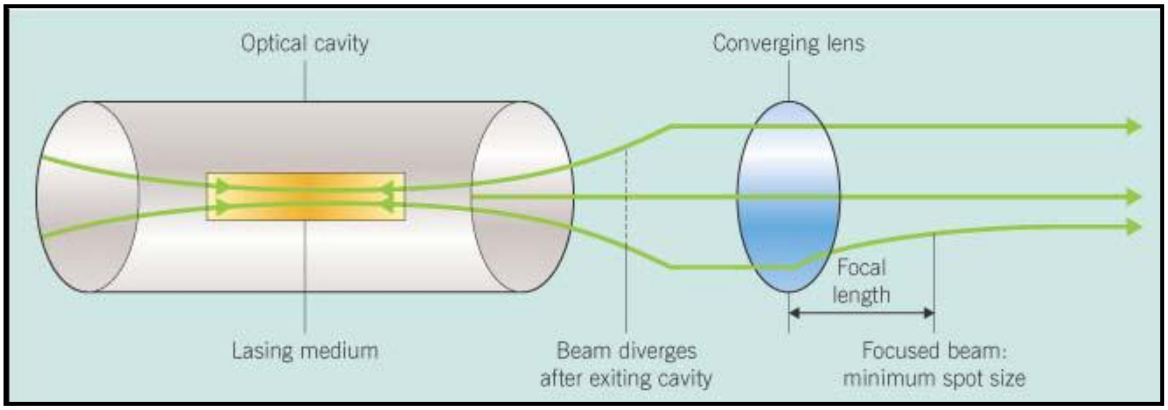

Figure 2: Divergence & convergence effect ***(Hirsch et al., 2008).***

PHOTOPHYSICS

The energy of a certain atom is dependent on the orbit where its electrons are present. When an atom is in its lowest energy level, which is called the ground state (E1), its electrons are in their lowest orbit, which is the closest to the nucleus. If this atom absorbs a photon, which is energy from an external source, its electrons move to a higher energy level (E2). This process is known as absorption and the atom is now in an excited state. The atom cannot stay excited for a long time, eventually its electrons return back to their lowest orbit and the atom restores its ground state. This process gives energy determined by the nature of the atom and is called "spontaneous emission of radiation". If an atom in the excited state is struck by another photon, its electrons can return to their basic orbital of the ground state with release of two photons of the same wave length and in phase with each other, this is the bases of laser ***(Peterson, 1980 and Pennino, 1991).***

COMPONENTS OF A LASER MACHINE

Any laser machine is composed of a power source, an active media, a resonating tube or optical cavity, and a delivery system **(Fig. 3)**. A power source such as a high powered flash lamp may be used in some types of lasers for example pulsed dye lasers. An active media is the source of laser radiation; it may be gaseous as in CO_2 lasers, liquid as in dye lasers, or solid as in ruby lasers. A resonating tube or optical cavity contains the active medium and has mirrors at each end that allows the photons emitted to bounce back and forth. A delivery system can be a fiber-optic cable or an articulating arm with mirrors. A lens or other focusing devices may be attached to the end of the delivery system to focus the energy to a small spot size ***(Pennino, 1991).***

The energy from the power source excites the atoms of the active medium or pumps the system into an excited state. Excited atoms spontaneously return to a stable state. Population inversion situation occurs, when most atoms are in the excited state. The energy produced when an atom goes from an excited state to a ground state is dissipated into the form of heat, photons of light are emitted. The mirrors at each end of the optical cavity allows photons of light emitted to bounce back and forth, in turn stimulating atoms in the excited state to return to their stable state in a logarithmic progression. The result of this chain reaction is the production of an enormous amount of light energy in brief period ***(Spicer and Goldberg, 1996).***

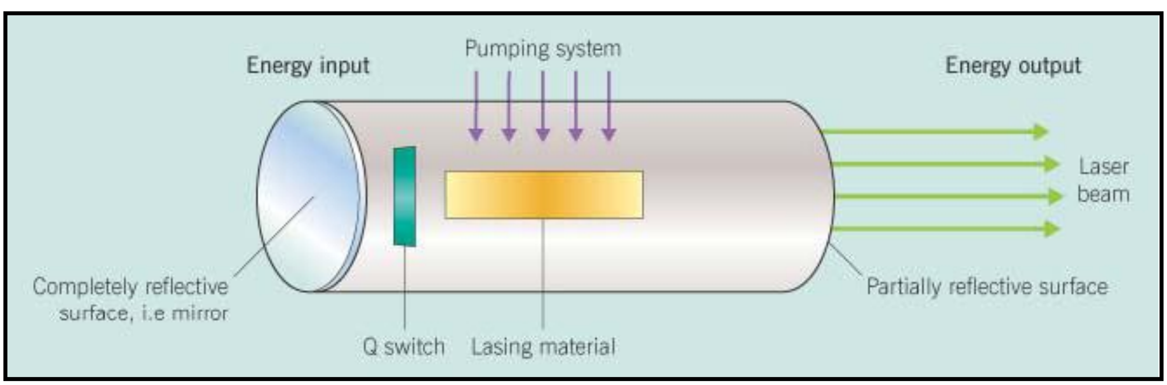

Figure 3: Laser system ***(Hirsch et al., 2008).***