The effects of femtosecond laser on retina

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ABSTRACT

Femtosecond laser plays an important role in cataract surgery, but retinal safety limits for near infrared laser employed in surgery are not well accuracy . This search determined retinal injury thresholds for protection from light scattering on bubbles and tissue fragments producing by laser cutting.

The aim of this research was to investigate possible retina damage under femtosecond (fs)-LASEK conditions and to optimize external parameters during surgery for reducing risk potential, such as pulse energy . Theoretically results indicated possible retinal damage, so this research tried to minimized these damages and get a good results theoretically.

KeyWords: Damage threshold ; femtosecond laser cataract surgery; retinal thermal damage.

Introduction

An exceimer laser was used to ablate the corneal surface tissue in the photorefractive keratomileusis (PRK) procedure (1). In 1990 the laser in situ keratomileusis (LASK) use a mechanical microtomecuts a thin flap in the corneal tissue (2) . Most of complications during LASK are caused by the fine cut of the microtome (3).Instead of mechanical devices, the cutting is done by focusing ultra-short laser pulses into the corneal tissue, these applications have been studied since its production (4). Studies about the risk potential of fs-LASK surgery were presented first in 2005 and 2006 (5-6) and have been continued and complemented within study.
Over the last few years, international studies in femtosecond (fs) technology and its applications have been carried out concerning the side effects on the cornea and lens[7-10]..

Method

1.Laser system:

In this research suppose that theoretically using laser of 10W, continuous wave of 1030 nm, with beam diameter of 2.6mm, so maximum that could be delivered to the eye was 3.6W.

2. Determination of thresholds:

The using of the common laser of control the power, a combination of half- wave by using a system of polarization. The retina damage thresholds under fs-LASIK conditions were determined dependent on varying laser parameters, such as irradiation time (t_{min} = 20 s, t_{max} = 150 s),numerical apertures (NA = 0.08, 0.23, 0.4 and 0.47) an dirradiation power (P_{min} = 500 mW, P_{max} = 1520mW).

3. Influence of temperature:

The thermal properties of the tissue layer were derived based on the reported water content of each layer (11-13). Assuming that the heat capacity and thermal conductivity would be scattered average of the properties of water and hydrated proteins (14-15) which make up the reminder of material. The density of tissue was assumed to be that of pure water fat(16) at 37C°. The optical absorption coefficient for the retinal and choroid layers were taken from (17). Fig. (1-2) show the relationship parameters of neural retina and retinal pigment.

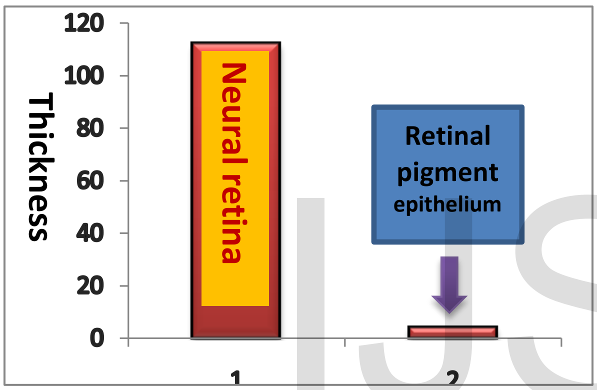

Fig. (1): shows the relationship of thickness between Neutral retina and Retinal pigment epithelium

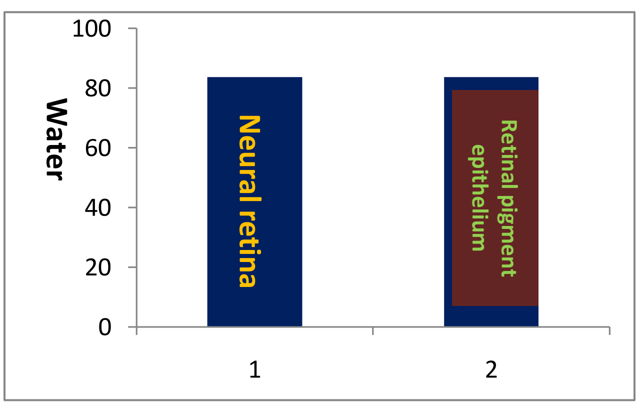

Fig. (2): shows the relationship of water content between Neutral retina and Retinal pigment epithelium

The Heat Capacity in (J/kg.K) is the same between Neutral retina and Retinal pigment epithelium, as shown in Fig. (3). As well as the Thermal Conductivity (Wm.K) is also the same as shown in Fig(4). That mean is the influence of temperature as the result of laser beam is the same.

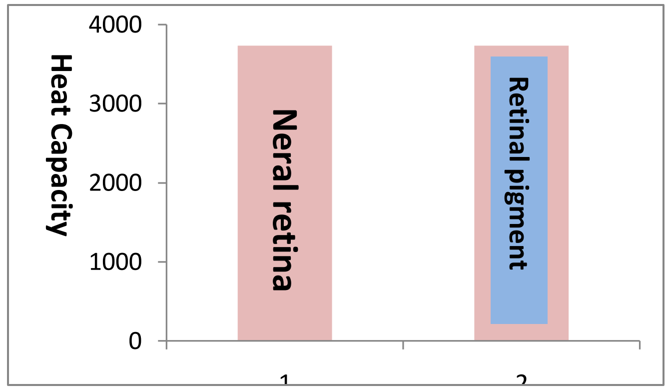

Fig. (3): shows the heat capacity between the Neutral retina and Retinal pigment epithelium is the same.

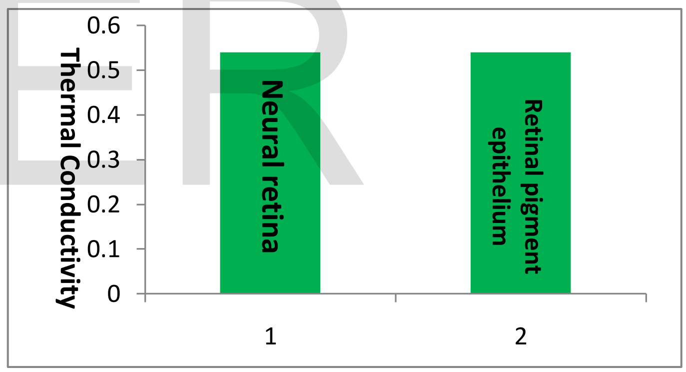

Fig. (4): shows the thermal conductivity between the Neutral retina and Retinal pigment epithelium is the same.

For the absorption of heat Fig.(5) shows that Retinal pigment will be absorbed more energy than Neutral retina ,it is very important for selected wavelength for minimize retinal damage .

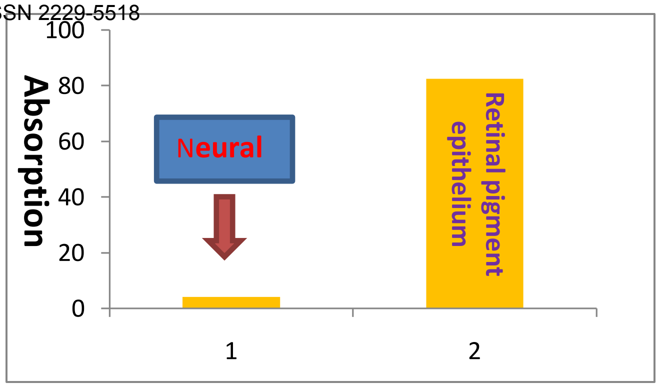

Fig. (5): shows the absorption of heat between the Neutral retina and Retinal pigment epithelium.

Temperature dynamics were calculated by numerically solving the bio-heat equation;

$$\rho C_p \frac{\partial T}{\partial t} = \nabla \bullet (k \nabla T) + Q(r,z,t). \quad \text{------} \quad (1)$$

In the equation, ρ is the density of the tissue, Cp is the heat capacity in the tissue layer, k is the thermal conductivity, and Q is the volumetric heat source term. The initial temperature was 37°C throughout the model and the boundaries of the computation domain had a fixed temperature condition at 37°C.Also we can say that laser heating is treated using Beer-Lambert law for absorption in non-scattering medium (17).

4. Other parameters which influence on cataract surgery:

To study the damage of human eyes, should be describe the anatomy of the human eye by using the Gullstrand model(19)is used in determining the irradiance profile. During capsulotomy, the Gaussian laser beam is focused through water or tissue with similar refractive index with an NA of 0.1 (angle for 1⁄e) on the anterior lens capsule, which is roughly 20.3 mm above the retina. For the 1030 nm wavelength, this results in a beam radius of ~1.5 mm on the retina.

For calculating a conservative safety threshold power by assuming a stationary beam and applying the ANSI standard following the retinal irradiance interpretation done by Delori et al.(20-21).

For the 1030 nm wavelength and retinal beam radius of1.3 mm, the maximum permissible power $P = 0.495t^{-0.25}$ W. From the typical pulse energy, pattern size, and spot spacing listed above, can calculate that the total energy E = 4.17 J is needed to form both capsulotomy and lens segmentation patterns. Assuming that the whole treatment is carried out with the same pulse energy and repetition rate, the fastest laser procedure that is within the ANSI safety limits can be delivered in $t = E⁄P = (E/ 0.495)^{4/3}$. For the total energy E listed above t = 17 s. The maximum average power P = E⁄t is then~0.25 W and for the pulse energy of 6 μJ, the maximum repetition rate is approximately 42 kHz. See Fig. (6).

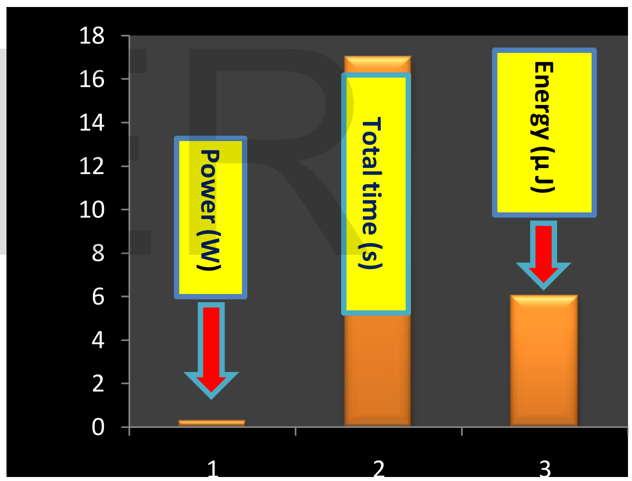

Fig. (6): shows the relationship between the time, Power and energy.

5. Reduce the complexity of the pulsed of laser beam:

The pulsed laser as a CW laser with the same average power. The typical femtosecond laser in cataract surgery operates with repetition rates between 10 and 100 kHz, which translates to 10 to 100 μs between pulses. This speed makes the CW approximation valid for the crucial retinal and choroid layers because the beam radius (~1.3 mm) is large compared to the spot spacing(5 to 10 µm) and the thermal diffusion length for the time between pulses (~2–7 µm)(22).

6. External factors which affects the optical power reaching the retina:

There are two factors affect the optical power reaching the retina a) plasma absorption and b) \\\bubble scattering. For attenuation plasma absorption and bubble scattering, can used a Ti: Sapphire(Tsunami, Spectra-Physics, Santa Clara, CA) femtosecond laser operating at 1 kHz with λ = 800 nm and τ = 150 fs. Fig(7). A half-wave plate and polarizing beam splitter were used for attenuation. Responsible finally for scattering laser light from subsequent treatment scans can using gelatin or without using gelatin the residual bubbles trapped in the lens tissue, can scatter laser beam.

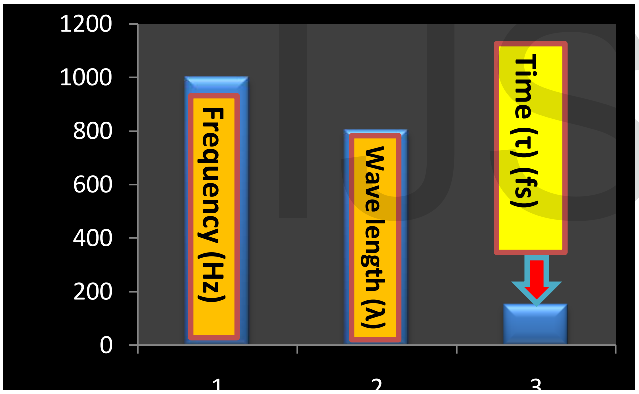

Fig. (7): shows the normal operating Femtosecond laser.

Results:

1. Theoretically and with helping other references can show that highest corneal powers without damage were 1.08 W for 10 s perfused treatment Fig (8), and the power between (o72- 0.28) W is non-perfused treatment Fig (9).

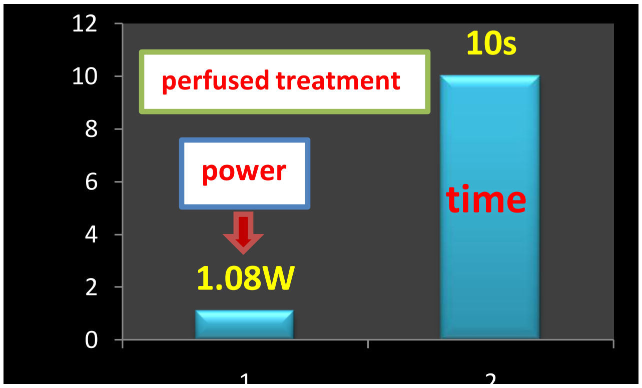

Fig. (8): shows the perfused treatment when the Power 1,08W during 10s.

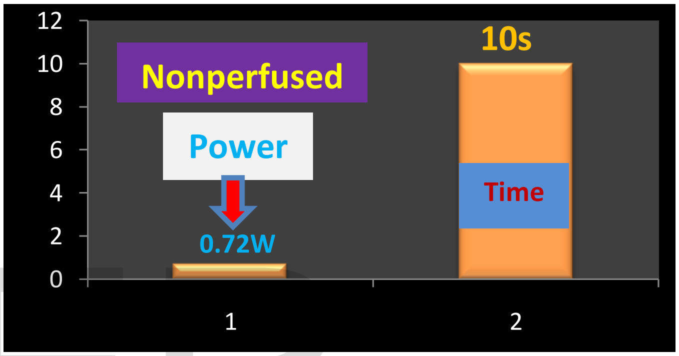

Fig. (9): shows the non-perfused treatment when the Power 0.72 W during 10s.

2. Peak temperature rise at the 10 s damage threshold is 23.8°C perfused and24.6°C non perfused, while peak temperature rise at the 100s damage threshold is 11.7°C perfused and 12.6°C non perfused. Figures (10-11) .

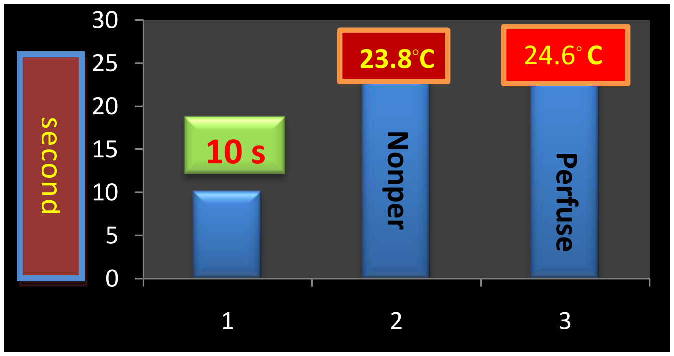

Fig. (10): shows peak temperature rise at 10 s damage thresholds.

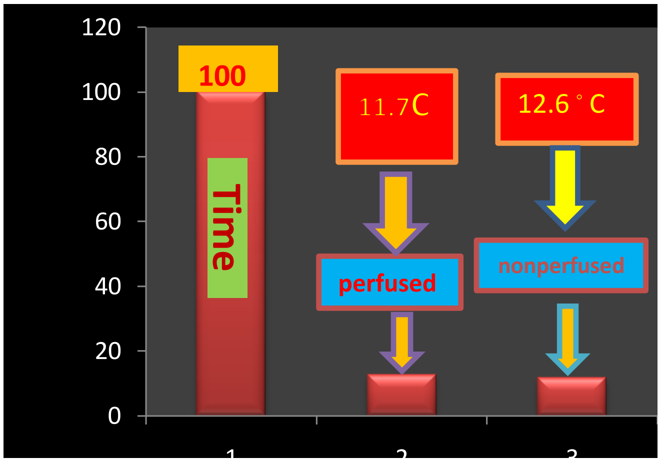

Fig. (11): shows peak temperature rise at 100s damage thresholds.

3. The retinal beam size of ~700 fs pulses at a 1030-nm wavelength can be modeled safely using Gaussian beam propagation although shorter pulses may require. Otherwise less no reaction will happen, more retina damage will be.

4. The retina damage thresholds under fs-LASIK conditions were determined dependent on varying laser parameters, such as irradiation time (tmin = 20 s, tmax = 150 s), numerical apertures (NA = 0.08, 0.23, 0.4 and 0.47) and irradiation power (Pmax = 500 mW, Pmin= 152 mW). Figures (12-13-14).

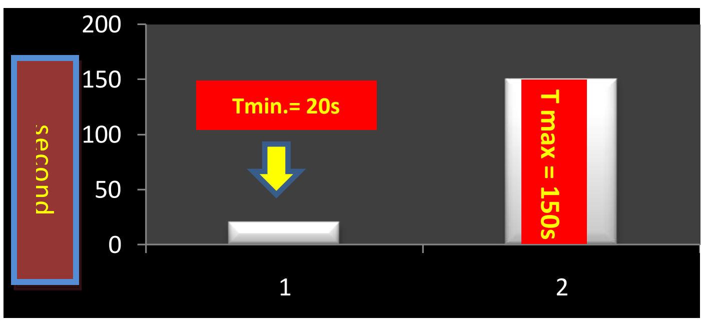

Fig. (12): shows the retina damage thresholds dependent on irradiation time.

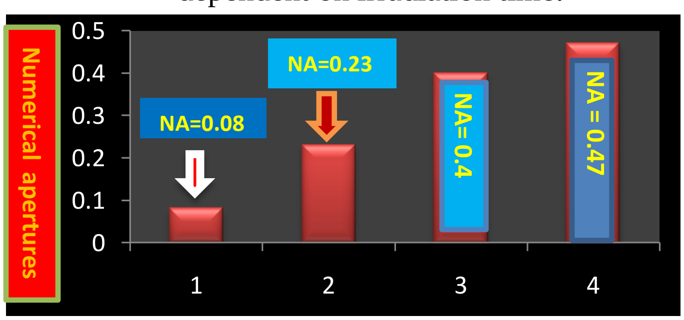

Fig. (13): shows the retina damage thresholds dependent on irradiation time numerical apertures.

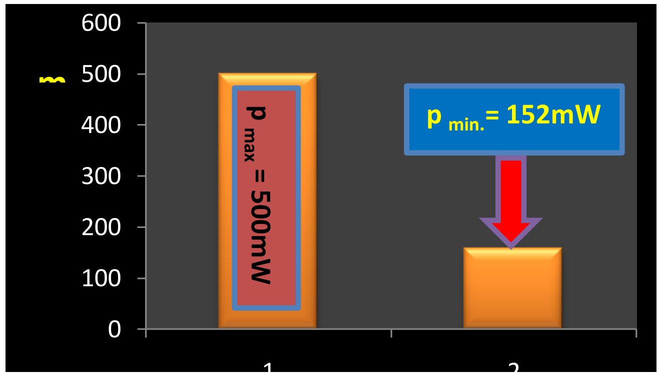

Fig. (14): shows the retina damage thresholds dependent on irradiation power maximum and power minimum.

Discussion:

Recently the study effects of femtosecond laser on retina are very important in the medical physics and ophthalmology. Thus in this research found that there are many parameters of femtosecond laser can be controlled to get a good results. First study the relationship between power total time and energy, Fig.(15)

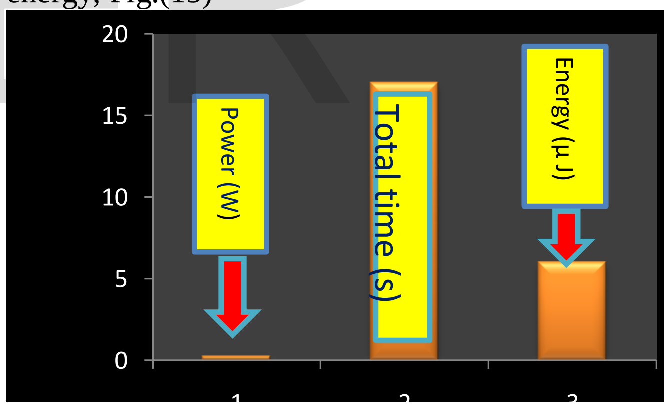

Fig. (15): shows the relationship between power total time and energy, more time it means that less power and energy.

Second study the relationship between frequency and wavelength depend upon minimum time in femtosecond as shown in Fig. (16).

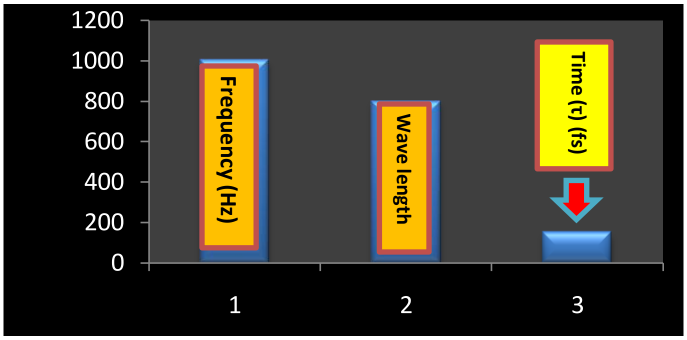

Fig. (16): shows the relationship between frequency and wavelength depend upon minimum time in femtosecond.

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