APPLICATION OF FEMTOSECOND LASER IN KERATOPLASTY

Essay
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ABBREVIATIONS

AC: Anterior Chamber

AK:Astigmatic keratotomy

ALK: Anterior Lamellar Keratoplasty

AMO: Advanced Medical Optics

ASOCT: Anterior Segment Optical Coherence Tomography

BCVA : Best Corrected Visual Acuity

BSCVA: Best Spectacle Corrected Visual Acuity

D : Dioptre

DALK : Deep Anterior Lamellar Keratoplasty

DLEK : Deep Lamellar Endothelial Keratoplasty

DLK : Diffuse Lamellar Keratitis

DSAEK: Descemet's Stripping Automated Endothelial Keratoplasty

DSEK : Descemet's Stripping Endothelial Keratoplasty

FDA: Food and Drug Administration

fs:femtosecond

FSL: Femtosecond Laser

IOP: Intraocular Pressure

IR: Infra-Red

J: Joule

KHz: Kilo Hertz

KP: Keratoplasty

LAR: Laser Arcuate Wedge Shaped Resection

LASIK: Laser in situ Keratomileusis

LIOB: Laser Induced Optical Breakdown

MHz: Mega Hertz

mJ: Milli Joule

MK :Microkeratome

mm: Millimeter

Nd: Neodymium-Doped

YAG: Yttrium Aluminium Garnet

nJ: Nanojoule

nm: Nanometer

ns: Nanosecond

OBL: Opaque Bubble Layer

OCT: Optical Coherence Tomography

PK: Penetrating Keratoplasty

PLD :Posterior lamellar disc

PLK : Posterior lamellar Keratoplasty

PRK: Photorefractive Keratectomy

Ps: Picoseconds

TLSS: Transient Light Sensitivity Syndrome

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Introduction

We are now entering a new era, where the field of refractive surgery is rapidly evolving by the FSL. The invention of the laser in 1960 stimulated renewed interest in optical physics and gave rise to a number of new research fields. One of them was the field of ultrafast optics, which had the beginning in the mid-1960s with the production of nanosecond (10^{-9} s) pulses by the first mode locked laser. Today, ultra short pulse generation remains the subject of active research. Rapid progress in this field has led to the creation of practical and useful lasers that can now produce pulses on the femtosecond (10^{-15} s) time scale **(Wayne and Knox, 2000).**

The prototype of the first ophthalmic surgical FSL system was designed and constructed by Dr Juhasz and his associates (1990).The design, development, and analysis of clinical laser parameters for use in corneal surgery were done in (1994).The intralase corporation was founded in (1997).Advances in ultra-fast laser technology continue to improve the surgical safety , efficiency , speed , adversatility of FSL in ophthalmology.**(Soong and Malta , 2009).**
The FSL is a near-infrared laser;similar to the Nd:YAG laser.The Nd:YAG laser has a pulse duration in the nanosecond (10^{-9} second) range .By shortening the pulse duration of the near-infrared laser from the nanosecond (10^{-9} second) to the picosecond (10^{-12} second) and then to the Femtosecond

(10^{-15} second) ,the zone of collateral tissue damage is progressively reduced **(Soong and Malta , 2009).**

The laser essentially vaporizes small volumes of tissue by photodisruption, producing a plasma shock wave cavitation and gas (CO2 and H2O) bubbles. Unlike lasers employing visible wavelengths, the ability of the FSL to cut corneal tissue is less hampered by optical haze, making it more useful in treating edematous or otherwise opacified corneas. The laser spots may be fired in vertical pattern for trephination (side) cuts or in a spiral or raster (zigzag) pattern to achieve lamellar cuts **(Colin and Malet , 2007).** By generating microplasmas inside corneal stroma with femtosecond pulses, it is possible to achieve a cutting effect inside tissue while leaving the anterior layer intact **(Lubatschowski et al; 2008).**

FSL technology seems to offer a promising approach to minimally invasive posterior keratoplasty through small tunnel incisions in corneal endothelial diseases. FSL enables the surgeon to cut cornea none mechanically with cutting accuracy of +/- 10 microns**(Seitz B et al; 2003).**

With the energy and firing pattern controlled by computer, the laser is capable of cutting tissue at various depths and patterns, producing minimal inflammation or collateral tissue damage **(Main et al; 2006).**

FSL increases the precision of ALK because of the highly reproducible dimensions of the cuts at the graft–host junction and the vertical side cut orientation (in comparison with horizontal using the mechanical microkeratome). The surgeon can better customize the shape and corneal dimensions of the donor

and recipient, improving the resulting fit and leading to less induced irregular astigmatism and interface haze. These features may result in faster and better wound healing, without the need for sutures **(Yoo et al;2008).**

FSL keratome produces a uniform thickness donor cap and recipient bed resection to eliminate interface mismatching seen in meniscus-shaped caps created using a mechanical microkeratome **(Sarayba et al;2005).**

The bladeless FSL assisted ALK, PLK and DSEK offer an exciting alternative to their manual and microkeratome-assisted counterparts. The FSL is also currently being used at some centers in the cutting of the donor posterior corneal buttons in DSAEK surgery **(Soong et al; 2008).**

Aim of the work

The aim of this study is to highlight the application of femtosecond laser in keratoplasty and to discuss its advantages and disadvantages.

Anatomy of the cornea

The cornea is the anterior part of the outermost layer of the eye. The cornea helps to protect the rest of the eye from germs, dust, and other harmful matter **(Hughes, 2008).**

Macroscopic anatomy :

The cornea is a transparent avascular tissue highly specialized to refract and transmit light with a smooth outer convex surface and inner concave surface. It forms part of what is almost, a sphere, but is usually more curved in the vertical than the horizontal meridian, giving rise to astigmatism with the rule **(Smolin and Foster, 2005) .**

Dimensions

The axial thickness of the cornea is 0.5mm centrally and its thickness increases gradually toward the periphery where it is about 0.7mm. The refractive index of the cornea is "1.4" **(Krachmer, et al, 2005).**

The front of the cornea appears elliptical, "11.7" mm wide in the horizontal meridian and "10.6" mm in the vertical meridian. On the other hand, the posterior surface is circular, "11.7"mm in diameter . The radius of curvature of the anterior surface is "7.8" mm, and of the posterior surface is "6.8" mm in the central third**(Hughes, 2008).**

Microscopic anatomy :

Behind the per-corneal tear film are five tissue layers :

- Epithelium.
- Bowman's layer.
- Stroma.
- Descemet's membrane.
- Endothelium**(Langston, 2007).**

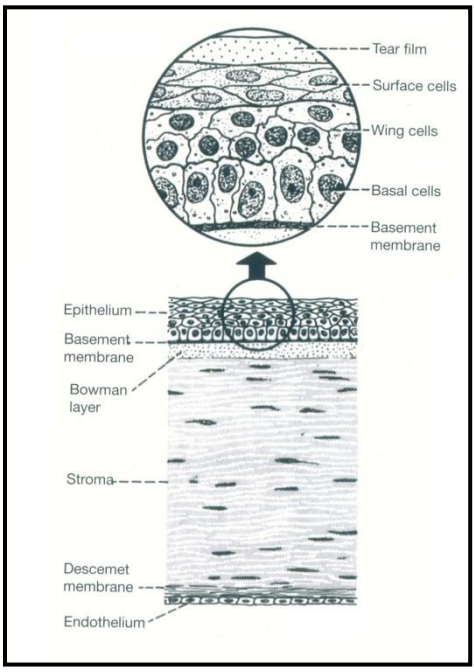

Figure (1): Microscopic anatomy of the cornea **(Kanski, 2007).**

1) Epithelium

Non-keratinized stratified squamous epithelial cells, the thickness of the corneal epithelium is approximately 50μm, which is about 10% of the total thickness of the cornea**(Hanna, et al, 1989).**

The corneal epithelium consists of five or six layers of three different types of epithelial cells :

a) Superficial cells

This includes two to three layers of terminally differentiated cells. These cells are flat and polygonal, 2 to 6μm in thickness, the cell membrane of these cells are characterized by extensive apical microvilli and microplicate which in turn are covered by a fine, closely opposed, charged glycocalyceal layer. Laterally adjacent superficial cells are joined by tight-junctional complex which restrict entry of tears into the intercellular space, thus a healthy epithelial surface repels dyes such as fluorescein and rose Bengal**(Hughes, 2008).**

b) Wing cells

Wing cells are two to three layers, so called because of their characteristic wing like shape, these cells are less flat than the overlying superficial cell, but possess similar tight, lateral, intercellular junction **(Doran, et al, 1980).**

c) Basal cells

A single layer of cuboidal basal cells that rests on the basement membrane(lamina lusida,25nm; lamina densa,50nm) in a palisade like manner in a perfect alignment. Neighbouring basal cells interdigitate