Applications of Femtosecond Laser in Corneal Surgery

Essay

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Introduction

Femto- (symbol f) is a prefix in the metric system denoting a factor of 10^{-15} or 0.000000000000001. Adopted by the 11th Conférence Générale des Poids et Mesures, it was added in 1964 to the SI (Système international d'unités). It is derived from the Danish word femten, meaning "fifteen". While Ahmed H. Zuwail the famous Egyptian scientist, won the Noble prize in 1999 for his work on femtochemistry. ***(Wikipedia online)***

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 FS (10^{-15} s) time scale. ***(Wayne and Knox, 2000)***

Lasers with ultrafast pulses have been developed to decrease the energy necessary to incise tissues and to decrease damage to surrounding tissue. ***(Sugar, 2002)***

The highly localized tissue effect of low energy femtosecond laser (FSL) may expand the capabilities and precision of this technology and may be used to create three- dimensional intrastromal resection with micron precision. ***(Ratkay-Traub, et al, 2003)***

The development of FSL technology has created new opportunities to advance corneal surgery, taking advantage of the unique anatomy and accessibility of the cornea. With the desire for minimal invasive procedure and predictable outcomes, this technology will advance the standard of care in corneal surgery in coming years. ***(Farjo and Farjo, 2009)***
FSL re-invigorated Laser in situ Keratomileusis (LASIK), simplified Intracorneal Ring Segments insertion (ICRS), and

re-invented corneal transplantation. They have brought precision to corneal surgery just as phacoemulsification brought precision to lens surgery. ***(Faktorovich, 2009)***

FSL is also used in correction of high astigmatic errors following Keratoplasty (KP) either by Arcuate Keratotomy (AK) ***(Buzzonetti, et al, 2009)*** or by Wedge Resection ***(Ghanem and Azar, 2006)***, Femtosecond laser-assisted diagnostic corneal biopsy (FAB) ***(Yoo, et al, 2008)***, Collagen Cross-linking (CXL) in early Keratoconus with riboflavin in a FSL created pocket ***(Kanellopoulos, 2009)***, Intrastromal correction of presbyopia (INTRACOR procedure) ***(Ruiz, et al, 2009)*** , Femtosecond laser Lenticule Extraction (FLEX) for correction of myopia ***(Ibrahim, 2009)*** and hyperopia ***(Sekundo, 2009)*** and Small-Incision Lenticule Extraction (SMILE) ***(Doane, 2009)*** and Femtosecond laser-Assisted Anterior Lamellar Corneal Staining–Tattooing (FALT)**.** ***(Kymionis, et al, 2009)***

The future of FSL in corneal and refractive surgeries may include new applications like the ones still under laboratory studies as Intralenticular FSL pulses for the restoration of accommodation ***(Schumacher, et al, 2008)*** and ***(Ripken, et al, 2008)*** , Intra-tissue Refractive Index Shaping (IRIS) of the cornea and lens using a low-pulse-energy FSL oscillator.
(Ding, et al, 2008)

After several years of development, new intraocular FSL designed for cataract surgery are beginning to garner attention, the initial clinical use of the LenSx Femtosecond laser (LenSx Lasers, Inc., Aliso Viejo, California) was very promising. ***(Nagy, 2009)***

Aim of Work

The aim of this work is to highlight the different applications of FSL in corneal surgery and to discuss its advantages over manual techniques, its disadvantages, limitations, side effects and recorded complications.

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)***

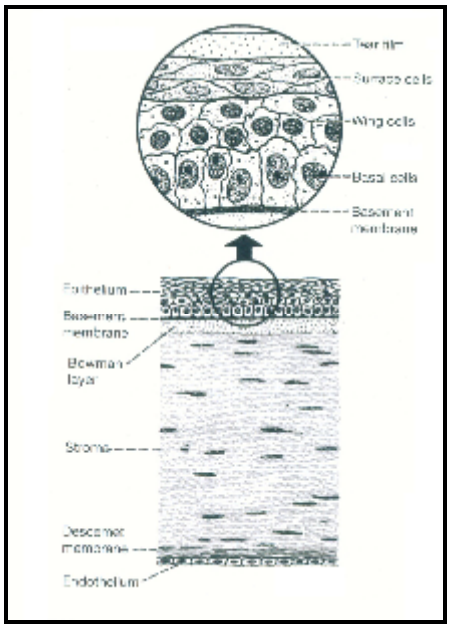

Figure (1): Microscopic anatomy of the cornea. ***(Kanski, 2007)***

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 characterized by extensive apical microvilli and microplicate which in turn 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