IMAGING OF CORNEAL LAYERS IN VIVO WITH ADVANCED OPTICAL TECHNIQUES

Essay

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By

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بسم الله الرحمن الرحيم

﴿اقرأ باسم ربك الذي خلق*
خلق الإنسان من علق * اقرأ
وربك الأكرم* الذي علم
بالقلم * علم الإنسان مالم
يعلم﴾

سورة العلق الاية ١-٥

Dedication

To the soul of my **Mother**

To my **Father**

To my **Wife** the eyes I see with

To the flowers of my life
My daughters **Salma** and **Gamila**

And to my **Brother**

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Mohamed Fawzy Oraby

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LIST OF ABBREVIATIONS

AD	Analog to digital
AS OCT	Anterior segment optical coherence tomography
CCT	Central corneal thickness
CES	Comprehensive eye scanner
CM	Confocal microscopy
EMBD	Epithelial basement membrane dystrophy
HSV	Herpes simplex virus
ICE	Iridocorneal endothelial dystrophy
INTACS	Intracorneal ring segments
LASIK	Laser in situ keratomileusis
LTK	Laser thermokeratoplasty
OCT	Optical coherence tomography
PKD	Posterior keratocyte density
PMMA	Polymethyl methacrylate
PPD	Posterior polymorphus dystrophy
PRK	Photorefractive keratectomy
PTK	Phototherapeutic keratectomy
RSOD	Rapid scanning optical delay
SLD	Super luminscent diode
SOCT	Spectral optical coherence tomography
TSCM	Tandem scanning confocal microscopy
UHR	Ultra high resolution
UP	Ultrasound pachymetry
UVA	Ultraviolet A

AIM OF THE WORK

The aim of this essay is to review principles, applications, advantages and disadvantages of advanced optical imaging techniques which are used for imaging of corneal layers in vivo.

INTRODUCTION

The cornea serves two specialized functions: It forms a protective barrier that shields the eye from the external environment and serves as the main refractive element of the visual system, directing incoming light through the lens for precise focusing on the retina.

Corneal diseases and refractive errors represent some of the most common ocular disorders among patients attending ophthalmology clinics. Worldwide, corneal infectious diseases have compromised the vision of more than 250 million people and have blinded over 6 million of them **(Smolin et al., 2004).**

Advances in imaging of the cornea in vivo, have provided new methods for studying pathological and post-surgical changes in the optical and biomechanical properties of the cornea. Imaging of the cornea is critical to improve the diagnosis, to assess the severity and progression, and evaluate the management of corneal diseases. Advances have been rapid, with improvement in hardware (such as light sources &imaging chips), optics (such as adaptive aberrations compensation) &soft ware (such as image tracking). Advances in optical imaging techniques include confocal microscopy, using Scheimpflug principle and optical coherence tomography **(Wolffsohn et al., 2007).**

Visible light constitutes the major ophthalmic imaging modality as it is the most accessible to the observer's naked eye. However, wavelengths outside the visible spectrum are used in new modalities such as optical coherence tomography (OCT) **(Morishige et al., 2006).**

Confocal microscopy is based on directing a white light through a point or a slit which is focused on to a small volume in the living cornea and a simultaneously placed confocal point (pinhole) or slit detector is used to collect the resulting signal. This optical alignment excludes or reduces the out of focus reflected signal from above or below the focal plane. Because only one tiny volume of the cornea is obtained by each point or slit source detector a useful wide field of view of the cornea could be regained by rapid synchronous movement of the illuminator and detector. As a result, in vivo non invasive imaging of corneal layers can be performed in pathological and post operative conditions **(Smolin et al., 2004).**

Imaging technique based on Scheimpflug principle is performed with a camera placed at an angle to a slit beam to create an optic section of the cornea. This technique has been used for the assessment of keratoconus, corneal clearance, corneal implants and corneal thickness. Scheimpflug measures of central corneal thickness (CCT) are accurate and have good repeatability compared with other contact pachymetry techniques **(Abad et al., 2007).**

Optical coherence tomography (OCT) is a non contact imaging technology based on the principle of low coherence interferometery. OCT allows in vivo cross sectional imaging of tissues (tomography). Anterior segment optical coherence tomography (AS OCT) improves the evaluation of corneal and refractive surgical procedures such as Lasik flaps, intracorneal rings, lamellar and penetrating Keratoplasty **(Christopoulos et al., 2007).**

The cornea is an excellent example of the unification of structure and function that combine to yield an almost perfectly transparent, avascular optical tissue that also serves as a barrier between the environment and the inside of the eye (**Edelhauser and Ubels , 2003).**

The transparent cornea forms the anterior one sixth of the eyeball; seen from the front the cornea is convex but somewhat elliptical in shape**.** Although the dimensions of the cornea vary considerably from one person to another, the approximate measurements are about 10.6 mm vertically but about 11.7 mm horizontally. Posteriorly, the cornea is concave and circular, measuring about 11.7 mm in diameter. The cornea is thinnest at its center, measuring about 0.5 to 0.6 mm and thicker at the periphery, measuring about 0.7 mm **(Snell and Lemp, 1998).**

Histology of the adult cornea

I) Layers

The histological structure of the cornea comprises five distinct layers:

- The epithelium
- Bowman’s layer
- The stroma
- Descemet’s membrane
- The endothelium

A) Epithelium

The non-keratinized squamous stratified epithelium consists of three morphologically different cell types (**Fig. 1**) (**Kaniski, 2007**):

1) An average of 2-3 layers of flat polygonal surface cells, located most superficially, containing apical microvilli in contact with the tear film. These cells are joined by tight junctions, adherens junctions and desmosomes, restricting the entry of tears into the intercellular spaces and providing mechanical strength between adjacent cells (**Ban et al., 2003**).

2) 2-3 layers of intermediate wing cells.

3) A single layer of columnar basal epithelial cells. These basal cells are approx. 20 µm tall and show a limited division capacity (**Ehlers and Hjortdal, 2006**). Basal cells serve as the source for differentiation into wing and superficial cells. Hemidesmosomes attach basal epithelial cells to the underlying basement membrane. The 0.05 µm thick basement membrane is composed mainly of type IV collagens and laminins produced by the basal epithelial cells (**Tuori et al., 1996**). Stem cells are located in Vogt's girdles in the corneal limbal area **(Lavker et al., 2004; Sun and Lavker, 2004**). These cells are continuously proliferating, providing a resupply for shedding epithelial cells, thus maintaining corneal integrity. A complete turnover of corneal epithelial cells occurs in 7 to 10 days (**Ehlers and Hjortdal, 2006**).