The Role of Corneal Hysteresis in Prediction of the Fate of Refractive Surgeries

An essay submitted for partial fulfillment of Master Degree in Ophthalmology

By

Ahmed Mohammed Samy Mohammed Ahmed
M.B.B.Ch.

Supervised by

Prof. Dr. Amr Saleh Galal

Professor of Ophthalmology
Faculty of Medicine
Ain Shams University

Dr. Reham Fawzy ElShinawy

Lecturer of Ophthalmology
Faculty of Medicine
Ain Shams University

Faculty of Medicine
Ain Shams University
Cairo-2013

To ALLAH

*Thanks to **ALLAH** who continues to bless and fill me with hope, faith and patience that enable me to carry out all my daily functions.*

To my family

*I would like to express my gratitude and gratefulness to **my family** specially **my mother**. Indeed I shall never forget her help all over my life.*

Contents

ACKNOWLEDGEMENT

I would like to express my deepest gratitude and respect to ***Prof. Dr. Amr Saleh Galal*** professor of ophthalmology Ain Shams University, for giving me the privilege to work under his supervision, for his generous guidance throughout this work. His kind supervision, continuous encouragement and endless support will always be engraved within my memory.

It was my great honor work under kind supervision of ***Dr.Reham Fawzy ElShinawy*** Lecturer of Ophthalmology Ain Shams University. I will remain indebted to her for her assistance, sincere advice, constructive criticism and supervision to ensure accuracy of this work. Without her help this work would have never been completed.

I would like to express special thanks to ***all staff members*** of ophthalmology department at Ain Shams University for their continuous assistance and support.

I would like to extend my gratitude to ***all my colleagues*** for their support and helpful attitude.

Ahmed Mohammed Samy

List of abbreviations

AL…………………………………………Axial Length

BCVA……….…………………Best Corrected Visual Acuity

CCT……………………………...Central corneal thickness

CESS………………..……… Corneal effort staging system

CH……………………………….………...Corneal Hysteresis

CPACG……..........…Chronic Primary angle closure glaucoma

CRF…………………..…………... Corneal resistance factor

CXL ………………..…..…....Corneal collagen cross-linking

D……………….………….....……………….…….…..Diopter

DA…………………..……...……Corneal deformation amplitude

DALK………..…………….Deep anterior lamellar keratoplasty

Epi-LASIK ………...……. Epipolis laser in-situ keratomileusis

FCD……………………..……..... Fuchs' corneal dystrophy

FFKC………………….……..…….. Forme fruste keratoconus

fLASIK ……………………...………..Femto-second LASIK

GAT…………………...…. Goldmann Applanation Tonometer

GON……………………………glaucomatous optic neuropathy

GS………………….……………………...….Glaucoma suspect

ICRS …………….........…. Intra-stromal corneal ring segments

IOL……………….……….……………………Intra ocular lens

IOP……………….……..………....…….Intraocular pressure

IOPcc ………….. Corneal-compensated Intraocular Pressure

IOPg…………..…Goldmann-correlated Intraocular Pressure

IR……………...…………….………………………. Infrared

KC……………………………………….………Keratoconus

LASEK …....... Laser Assisted Sub-Epithelial Keratomileusis

LASIK……………….……..…… Laser in situ keratomileusis

µm…………….………..…...……….………Micrometer

mmHg……………………...….…. Millimeters of mercury

mo…………………………………………………..Month

ms…………………..…………..…………….Milliseconds

NTG ………………..………......Normal tension glaucoma

NS……………………….……………………..not significant

OHT………………..……….……..……. Ocular hypertension

OHTS………………... Ocular Hypertension Treatment Study

ORA ………………..…………..…Ocular response analyzer

Ortho-k………………………Orthokeratology Contact Lenses

OZ ………………………………………..….optical zone

P_1…………………………………First applanation pressure

P_2……..……………………..…Second applanation pressure

P-value…………………………..…..….…….Probability value

PEX…………………………...pseudo-exfoliation syndrome

PKP………………………………….... Penetrating keratoplasty

POAG ………………….……...…. Primary open angle glaucoma

PRK…………………...…………. Photorefractive keratectomy

PTK ………………...………….. Phototherapeutic keratectomy

R2…………………………....The coefficient of determination

SBK ……………...…………..…Sub-Bowman's keratomileusis

SD……………..……………………………Standard deviation

SE………………………………...…. Spherical equivalent

UCVA…………………………...…Uncorrected Visual Acuity

UV-A…………………………...…………..…..Ultraviolet A

Wk……………………………….……………………..week

List of figures

Page

List of tables

Corneal Hysteresis (CH) is the difference in the inward and outward pressure values obtained during the dynamic bi-directional applanation process employed in the Ocular Response Analyzer (ORA), as a result of viscous damping in the cornea. *(Luce DA, 2005)*

CH is an important indication of the biomechanical properties of the cornea as an indicator for the viscous damping. That is the ability of the tissue to absorb and dissipate energy; a property that is determined by the visco-elastic properties of the corneoscleral shell. *(Brown KE and Congdon NG, 2006)*.

CH can be measured in vivo by the ORA using an applied force-displacement relationship. An air jet similar to that used in traditional air-puff tonometers generates force or pressure on the cornea. *(Goldberg AL, 2005)*

It was found that because CH is capable of assessing the biomechanical properties of corneal tissue, it is possible to identify and categorize various corneal conditions by means of measurable and repeatable metric measurements, in Comparing the CH measurements of eyes with known corneal conditions to normal subjects measurements reveals significant differences *(Goldberg AL, 2005)*which lead some experts to theorize that clinically normal eyes which exhibit significantly lower than average CH may be at risk of developing corneal disorders in the future *(Shah S, et al., 2009)*.

It is easy to see that the CH and corneal resistance factor (CRF) measurements in the eyes with corneal Conditions as Fuchs` Corneal Dystrophy (FCD) *(Brown KE and Congdon NG, 2006)*, keratoconus (KC) and post laser in situ keratomileusis (LASIK) surgeries are on average significantly lower than in normal eyes *(Medeiros FA and Weinreb RN, 2006)*.

The mean CH was 10.7 $_{\text{mmHg}}$ in normal eyes compared with 9.6 $_{\text{mmHg}}$ in keratoconic eyes. Also CH values related to the severity of the disease as it is decreasing with the severity of the disease. The ORA may also be useful to assess progression of disease, as CH may change before topographic or clinical changes becoming apparent. This may make the ORA useful to help deciding how to manage KC such as the chance of proceeding to keratoplasty, so corneal biomechanical measurements may prove to be useful for the preoperative screening of refractive surgery candidates and may help clinicians to choose between surface ablation techniques as photorefractive keratectomy (PRK) and incisional procedures such as LASIK *(Fontes BM, et al., 2010)*

Corneal biomechanics can be reinforced by various methods such as Intrastromal Corneal Ring Segments (ICRS), conductive keratoplasty and corneal collagen cross-linking (CXL) using riboflavin. *(Qazi MA, et al., 2009)*

This valuable new information about the CH enhances the ability to make complex decisions in a number of important subjects as to increase the confidence in evaluation of refractive surgery candidates *(Kamiya K, et al., 2008)* and to predict which patients stand the greatest risk for postoperative ectasia *(Brown KE and Congdon NG, 2006)*, also It can Improve the ability to detect KC *(Medeiros FA and Weinreb RN, 2006)* ,so The role of corneal biomechanics is therefore important to be considered in routine LASIK or surface ablation procedures and in special cases where the biomechanical status of the cornea is abnormal e.g. after any previous refractive surgery or after penetrating keratoplasty (PKP). *(Smolek MK and Klyce SD, 2000)*

Better understanding of the corneal biomechanics might allow for improved predictability of refractive surgery outcomes and may also improve the preoperative identification of eyes at risk of developing ectasia after refractive surgery, ORA is an attempt to make the measurement of rigidity and elasticity easily accessible to clinicians for all patients. Measuring corneal biomechanical properties by applying a force to applanat the cornea requires a procedure capable of separating the contributions of the corneal resistance and the intraocular pressure (IOP) because the corneal resistance and true IOP are basically independent *(Abitbol O, et al., 2010)*

Hysteresis: is a property of physical systems that do not instantly follow the forces applied to them, but react slowly, or do not return completely to their original state, For instance if you push on a piece of wet sponge it will assume a new shape, and when you remove your hand it will not return to its original shape, or at least not immediately and not entirely. The term hysteresis is derived from an ancient Greek word meaning 'coming behind'. The phenomenon was identified and introduced into scientific vocabulary in 1890 by the Scottish physicist, Sir James Alfred Ewing. He discovered hysteresis when he was studying magnetic systems that don't have a material substance but have elasticity and viscosity properties *(LAPSHIN R, 1995)*.

CH is a measure of viscous damping in the corneal tissue. It is the "energy absorption capability" of the cornea *(Touboul D, et al., 2008)*.

CH is the difference between the inward and outward applanation pressure. The air pressure pulse which press on the corneal surface is a precisely metered jet of air. If the cornea was purely elastic, it would be expected that the cornea would applanate at the same pressure in both directions i.e. inward and outward; however, due to the viscoelastic properties of the cornea two different applanation pressures are noted. The CH is described as the loss or delay of energy due to resistance of the cornea to the air puff *(Shah S, et al., 2009)*, Hysteresis refers to the energy lost during the stress–strain cycle *(Kotecha A, 2007)*

To gain a better understanding of corneal biomechanical properties some terms should be defined:

Stress: is a measure of the internal forces acting within a body. Quantitatively, it is a measure of the average force per unit area of a surface within the body on which internal forces act; these internal forces arise as a reaction to external forces applied on the body. *(Da-Jian, et al., 2007)*

Strain: is the deformation in the material to which stress has been applied (applied force) it's directly proportional to stress (internal force), independent of the length of time or the rate at which the force is applied. *(Noll W and Truesdell C, 2004)*