



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

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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.*

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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

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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 corneal 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 mmHg in normal eyes compared with 9.6 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*)