

# **Corneal Hysteresis**

**An essay submitted for  
partial fulfillment of  
Master Degree  
in  
Ophthalmology**

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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  
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# **Contents**

	<b>Page</b>
<b>Acknowledgement.....</b>	<b>II</b>
<b>List of abbreviations.....</b>	<b>III</b>
<b>List of figures.....</b>	<b>VI</b>
<b>List of tables.....</b>	<b>IX</b>
<b>Chapter 1: Introduction and Definitions.....</b>	<b>1</b>
<b>Chapter 2: Factors affecting corneal hysteresis.....</b>	<b>6</b>
<b>Chapter 3: Measurement and assessment.....</b>	<b>19</b>
<b>Chapter 4: Corneal hysteresis in some corneal pathologies.....</b>	<b>30</b>
<b>Chapter 5: Corneal hysteresis in refractive surgery.....</b>	<b>44</b>
<b>Chapter 6: Corneal hysteresis in glaucoma.....</b>	<b>54</b>
<b>Summary.....</b>	<b>73</b>
<b>References.....</b>	<b>75</b>
<b>Arabic summary.....</b>	<b>85</b>

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## **List of abbreviations**

APON.....	Acquired pit of the optic nerve
Ave.....	Average
CCT.....	Central corneal thickness
CESS.....	Corneal effort staging system
CH.....	Corneal Hysteresis
COOH.....	Carboxyl group
CRF.....	Corneal resistance factor
CXL .....	Collagen cross-linking
D.....	Diopter
DNA.....	Deoxyribonucleic acid
ECM.....	Extracellular matrix
FCD.....	Fuchs' corneal dystrophy
FFKC.....	Forme fruste keratoconus
GAGs.....	Glycosaminoglycans
GAT.....	Goldmann Applanation Tonometer
GS.....	Glaucoma suspect
ICRS .....	Intra-stromal corneal ring segments
IOP.....	Intraocular pressure
IOPcc .....	Corneal-compensated Intraocular Pressure
IOPg.....	Goldmann-correlated Intraocular Pressure

IR.....	Infrared
LASEK .....	Laser Assisted Sub-Epithelial Keratomileusis
LASIK.....	Laser in situ keratomileusis
MHz.....	Mega hertz
µm.....	Micrometer
mmHg.....	Millimeters of mercury
mRNA.....	Messenger ribonucleic acid
ms.....	Milliseconds
N.....	Number
Nm.....	Nanometer
NTG .....	Normal tension glaucoma
OCT.....	Optical coherence tomography
OHT.....	Ocular hypertension
OHTS.....	Ocular Hypertension Treatment Study
ORA .....	Ocular response analyzer
P-value.....	Probability value
PACG.....	Primary angle closure glaucoma
PDCT.....	Pascal dynamic contour tonometer
PK.....	Penetrating keratoplasty
POAG .....	Primary open angle glaucoma
PRK.....	Photorefractive keratectomy

PTK .....	Phototherapeutic keratectomy
$R^2$ .....	The coefficient of determination
RMS .....	Root mean square
RNA .....	Ribonucleic acid
RNFL .....	Retinal nerve fiber layer
SE .....	Spherical equivalent
SO <sub>4</sub> .....	Sulfate group
St Dev .....	Standard of deviation
UV-A .....	Ultraviolet A



## **List of figures**

		<b>Page</b>
1	Rectangular specimen subject to compression	4
2	Corneal hysteresis versus central corneal thickness in normal population	9
3	Stromal microstructure	10
4	Steps of intracellular collagen biosynthesis	12
5	Steps of extracellular collagen biosynthesis	13
6	Correlation between intraocular pressure and corneal hysteresis	17
7	The ocular response analyzer	20
8	Method of operation of the ocular response analyzer	21
9	Measurement of corneal hysteresis using the ocular response analyzer	23
10	Corneal hysteresis distribution of a normal population	24
11	Corneal- compensated intraocular pressure versus central corneal thickness in a population of normal eyes	25
12	Relations of corneal hysteresis and corneal resistance factor to Goldmann-correlated intraocular pressure	27
13	Typical signal from a normal curve	29
14	Possible causes of low amplitude applanation signals	34
15	Comparison of Corneal Hysteresis distribution of normal, keratoconic and Fuchs' endothelial dystrophy subjects	34
16	Typical signals from a Fuchs' endothelial dystrophy eye	35

17	Differences in the biomechanical parameters provided by the ORA between keratoconus grades	37
18	Typical signal a keratoconus eye	38
19	Mean corneal hysteresis and corneal resistance factor in groups	39
20	Mean difference between corneal hysteresis & resistance factor in groups	39
21	Correlation between corneal hysteresis and spherical equivalent in diopters	41
22	Correlation between corneal resistance factor and spherical equivalent in diopters	42
23	Corneal hysteresis in the control and diabetic groups	43
24	Pre and Post LASIK corneal hysteresis	47
25	Signal from post-LASIK subject	49
26	A graph showing a significant decrease in corneal hysteresis and corneal resistance factor after phototherapeutic keratectomy	51
27	Relationship between central corneal thickness and intraocular pressure by Goldmann applanation in normal population	56
28	Typical Waveform from an eye with high intraocular pressure	60
29	Typical waveform from an eye with high intraocular pressure but normal corneal hysteresis	62
30	Corneal Effort Staging System	64
31	Signal obtained from the eye of a normal tension glaucoma subject	65
32	Inferior acquired pit of optic nerve	66
33	Central corneal thickness in the control and diabetic groups	67

34	Corneal compensated IOP, Goldmann-correlated IOP and Goldmann applanation tonometer in the control and diabetic groups	68
35	Corneal hysteresis and differential intraocular pressure in diagnostic groups	69
36	Distribution of corneal hysteresis measured by Reichert ocular response analyzer in children with normal healthy eyes and eyes with congenital glaucoma	70
37	Post-therapeutic correlation of the change in corneal hysteresis and the change in Goldmann-correlated intraocular pressure	71

## **List of tables**

<b>Table</b>		<b>Page</b>
1	Relation between CH and age	18
2	Hysteresis of normal, keratoconic and Fuchs' dystrophy subjects	35
3	Biomechanical properties before and after collagen cross-linking treatment	52
4	Correlation between corneal effort staging system and retinal nerve fiber layer	64

## **Chapter 1**

# **Introduction and Definitions**

## Hysteresis

Hysteresis is derived from an ancient Greek word meaning ‘coming behind’. It was introduced into scientific vocabulary about 120 years ago by the Scottish physicist, Sir James Alfred Ewing. He discovered hysteresis when he was studying magnetic systems that do not have a material substance but have elasticity and viscosity properties. 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. <sup>(1)</sup>

Identified by David Luce, corneal hysteresis (CH) is the difference in the inward and outward pressure values obtained during the dynamic bidirectional applanation process employed in the ocular response analyzer (ORA), as a result of viscous damping in the cornea. <sup>(2)</sup>

To gain a better understanding of corneal biomechanical properties some terms should be defined: <sup>(1)</sup>

- **Stress:** is the average amount of force exerted per unit area.
- **Strain:** is the deformation in the material to which stress has been applied.

**Strain** (deformation) is directly proportional to **stress** (applied force), independent of the length of time or the rate at which the force is applied.

- **Elasticity:** is the property of a substance that enables it to change its length, volume or shape in direct

response to a force and to recover its original form upon the removal of the force.

- **Viscosity:** is the resistance of a fluid (liquid or gas) to a change in shape, or movement of neighboring portions relative to one another. The more viscous a fluid is, the more it resists flow. Honey, for example, has a greater viscosity than water.

Resistance to an applied force depends primarily on the speed at which the force is applied.

- **A viscoelastic material:** is a material which has both viscous and elastic properties. The cornea is an example of a viscoelastic material. Viscoelastic materials are also able to recover their original shape after stress is removed, but the relaxation path is different from the deformation path. This behavior is referred to as hysteresis.
- **Damping:** is restraining of vibratory motion, such as mechanical oscillations, by dissipation of energy.
- **Poisson's ratio:** is a measure of **the Poisson's effect** (figure 1) which occurs when a sample cube of a material is stretched in one direction, it tends to contract (or occasionally, expand) in the other two directions perpendicular to the direction of stretch. Conversely, when a sample of material is compressed in one direction, it tends to expand (or rarely, contract) in the other two directions.<sup>(3)</sup>