The effect of Neodymium Yttrium Aluminum Garnet laser (Nd:YAG) treatment of posterior capsule opacification on anterior chamber depth in pseudophakic eyes

Thesis

Submitted for fulfillment of Master Degree in ophthalmology

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Ahmed Nasef Mohamed Abdelbaki
Dedication

To my parents

and my wife

To whom I am grateful beyond what any words can express, your unlimited sacrifice and sincere prayers can never be repaid

Dad and mom I owe you everything

Ahmed Nasef Mohamed Abdelbaki
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<td>AC</td>
<td>Anterior chamber.</td>
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<td>ACD</td>
<td>Anterior chamber depth.</td>
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<tr>
<td>aSMA</td>
<td>Alpha smooth muscle actin.</td>
</tr>
<tr>
<td>BAB</td>
<td>Blood aqueus barrier.</td>
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<td>BCVA</td>
<td>Best corrected visual acuity.</td>
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<tr>
<td>BFGF</td>
<td>Basic fibroblast growth factor.</td>
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<td>CTR</td>
<td>Capsular tension ring.</td>
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<tr>
<td>CTS</td>
<td>Capsular tension segment.</td>
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<td>CCC</td>
<td>Continuous curvilinear capsulorhexis.</td>
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<td>CME</td>
<td>Cystoid macular edema.</td>
</tr>
<tr>
<td>CPCO</td>
<td>Central PCO.</td>
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<tr>
<td>ECCE</td>
<td>Extracapsular cataract extraction.</td>
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<tr>
<td>EGF</td>
<td>Epidermal growth factor.</td>
</tr>
<tr>
<td>EMT</td>
<td>epithelial mesenchymal transition.</td>
</tr>
<tr>
<td>GAG</td>
<td>Glycosaminoglycan.</td>
</tr>
<tr>
<td>HGF</td>
<td>Hepatocyte growth factor</td>
</tr>
<tr>
<td>HLA</td>
<td>Human leucocytic antigen.</td>
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<tr>
<td>IGF</td>
<td>insulin like growth factor (IGF).</td>
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<td>IOP</td>
<td>Intraocular pressure.</td>
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<tr>
<td>LECs</td>
<td>Lens epithelial cells.</td>
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<tr>
<td>Nd:YAG</td>
<td>Neodymium Yttrium Aluminum Garnet laser</td>
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<td>NPE</td>
<td>Non pigmented epithelium.</td>
</tr>
<tr>
<td>NSAIDS</td>
<td>Non steroidal anti-inflammatory drugs.</td>
</tr>
<tr>
<td>OVD</td>
<td>Ophthalmic Viscosurgical Devices.</td>
</tr>
<tr>
<td>PAC</td>
<td>Peripheral anterior cortical cataract.</td>
</tr>
<tr>
<td>PAS</td>
<td>Periodic acid–Schiff.</td>
</tr>
<tr>
<td>PDGF</td>
<td>platelets derived growth factor.</td>
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<tr>
<td>POBH</td>
<td>posterior optic buttonholing</td>
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<tr>
<td>PPC</td>
<td>primary posterior capsulorhexis.</td>
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<td>PPCO</td>
<td>Peripheral PCO.</td>
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<td>PSCC</td>
<td>Posterior sub capsular cataract.</td>
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<td>PXF</td>
<td>Pseudoexfoliation.</td>
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<td>PC I.O.L</td>
<td>Posterior chamber intra ocular lens.</td>
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<td>SD</td>
<td>Standard deviation.</td>
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<td>TGFB</td>
<td>Transforming growth factor beta.</td>
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Introduction

Cataract surgery is one of the most common procedures performed worldwide. It is also one of the oldest treatments. Cataract surgery may be considered among the most successful treatments in all of medicine (Allen, 2006).

Posterior capsular opacification (PCO) is the most common long-term complication of cataract surgery in both phacoemulsification and extracapsular cataract extraction (ECCE). The incidences of PCO were 11.8% at 1 year, 20.7% at 3 years, and 28.4% at 5 years after surgery (Schaumberg, 1998).

At present, the only effective treatment of PCO is Neodymium Yttrium Aluminum garnet laser (Nd:YAG) laser capsulotomy, which involves clearing the visual axis by creating a central opening in the opacified posterior capsule (Apple, 2001).

Although this procedure is easy and quick, there are complications, including retinal detachment, damage to the IOL, cystoid macular edema, an increase in intraocular pressure, iris hemorrhage, corneal edema, IOL subluxation, and exacerbation of localized endophthalmitis (Aslam, 2003).

Several studies have demonstrated IOL movement after laser treatment (Findl and Drexler, 1999). Some studies reported a progressive decrease in anterior chamber depth (ACD) or no IOL movement at all, with no findings of statistically significant changes in the patients’ refraction (Thornval and Naeser, 1995).
Any significant change in IOL position can lead to a change in the patient’s refractive status, which will therefore require corrective lens prescriptions (Ozkurt, 2009).

Different methods as optical coherence tomography or A-scan ultrasound for more precise ACD measurement as well as IOL position can be used (Khambhiphant, 2015).
Aim of the Work

The aim of this work is to determine the changes in anterior chamber depth after Neodymium-Yttrium–Aluminum–Garnet (Nd:YAG) laser posterior capsulotomy using A-scan ultrasound.
Anatomical considerations

Lens development begins as surface ectodermal cells, overlying the bulging optic vesicle, thicken and form the lens placode. Soon thereafter, the placode is induced to invaginate into the forming optic cup. This process continues until the placode is transformed into an inverted lens vesicle. Then, the cells approximating the retinal or posterior half of the lens vesicle begin to terminally differentiate. As a consequence of this process, these cells are transformed from cuboidal epithelial cells into long fibers. Since they are the first fibers to develop, they are referred to as primary fibers. As primary fibers form, they obliterate the lumen of the vesicle. At this stage, the lens is composed of a ball of primary fibers, overlain on its anterior half, by a monolayer of cuboidal epithelial-like cells. The entire lens is enclosed in a basement membrane-like capsule that is produced by the basal membrane of its cells (Henry and Grainger, 1990).

Anatomy of the crystalline lens

The lens is an elliptical, biconvex avascular body. It is enveloped by a thick capsule, which is a basement membrane of the lens epithelium. The lens epithelial cells (LECs) line the interior surface of the anterior, pre-equatorial, and equatorial regions of the lens capsule. In the equatorial region of the lens, the LECs undergo terminal differentiation to form lens fibers that are laid down in a concentric manner. From the lens capsule to the center of the lens, these concentric layers of lens fibers are identified broadly as cortex and nucleus. The nucleus contains the oldest lens fibers while the newer ones lie superficially in the cortex (Figure (I) (Raj et al, 2007).
Crystallins are water-soluble proteins that compose over 90% of the protein within the lens (Hoehenwarter et al, 2008). The three main crystallin types found in the eye are α-, β-, and γ-crystallins. Crystallins tend to form soluble, high-molecular weight aggregates that pack tightly in lens fibers, thus increasing the refraction index of the lens while maintaining its transparency. β and γ crystallins are found primarily in the lens, while subunits of α-crystallin have been isolated from other parts of the eye and the body (Andley, 2006).

An important factor in maintaining the transparency of the lens is the absence of light-scattering organelles as the nucleus, endoplasmic reticulum, and mitochondria within the mature lens fibers. Lens fibers have also a very extensive cytoskeleton that maintains the exact shape and packing of the lens fibers; disruptions/mutations in certain cytoskeletal elements can lead to the loss of transparency (Bloemendal et al, 2004).

**Figure (I):** structure of human lens (Sharma & Santhoshkumar, 2009).
Lens structure:

The lens has three main parts: the lens capsule, the lens epithelium, and the lens fibers. The lens capsule forms the outermost layer of the lens and the lens fibers form the bulk of the interior of the lens. The cells of the lens epithelium, located between the lens capsule and the outermost layer of lens fibers, are found only on the anterior surface of the lens. The lens itself lacks nerves, blood vessels and connective tissue. (Duker et al., 2008).

a) Lens capsule:

The lens capsule is a smooth, transparent basement membrane that completely surrounds the lens. The capsule is elastic and is composed of collagen. It is synthesized by the lens epithelium and its main components are Type IV collagen and sulfated glycosaminoglycans (GAGs). The capsule is elastic and thus allows the lens to assume a more globular shape when not under the tension of the zonular fibers, which connect the lens capsule to the ciliary body. The capsule varies from 2 to 28 micrometres in thickness, being thickest near the equator and thinnest near the posterior pole. The lens capsule may be involved in the lower anterior curvature than posterior of the lens (Forrester et al., 1996).

B) Lens epithelium:

The lens epithelium, located in the anterior portion of the lens between the lens capsule and the lens fibers, is a simple cubical epithelium (Forrester et al., 1996)

The lens epithelium cells divide and differentiate into new lens fibers. It constantly lays down fibers in the embryo, fetus, infant, and adult, and continues to lay down fibers for lifelong growth (Andley, 2006).
The central cells are located near the anterior pole. They are polygonal with rounded nuclei that show no mitotic figures except when stimulated mechanically. The pre-equatorial and equatorial cells are the major sites of cell division. From these cells new cells migrate to the posterior surface to form lens fibers (Bron et al, 1997).

By examination with the electron microscope the epithelial cells show few organelles as rough endoplasmic reticulum, Golgy apparatus, free ribosomes and small mitochondria laid in coarse granular cytoplasm (Rafferty and Scholz, 1989).

The basal surface of the epithelial cells adheres to the capsule surface. The rest of the cell membrane is relatively complex. The lateral margin shows undulations while the apical membrane shows interdigitations with the underlying lens fibers. The cells are attached to each other’s by desmosomes and to the underlying capsule by hemidesmosomes. Gap junctions lie between the cells allowing free movement of small molecules. Gap junctions are infrequent between apical membranes and adjacent lens fibers. However the apical membranes are abundant of receptors mediating endocytotic transferring processes of metabolites (Bron et al, 1997).

c) Lens fibers:

The lens fibers form the bulk of the lens. They are thin, long, transparent cells and firmly packed with diameters typically between 4-7 micrometers and lengths of up to 12 mm long. The lens fibers stretch length wise from the posterior to the anterior poles and, when cut horizontally, are arranged in concentric layers rather like the layers of an onion. If cut along the equator, it appears as a honeycomb. The middle of each fiber lies on the equator. These tightly packed layers of lens fibers
are referred to as laminae. The lens fibers are linked together by gap
ejunctions and interdigitations of the cells that resemble “ball and socket”
forms (Forrester et al, 1996).

-The lens is split into regions depending on the age of the lens fibers
of a particular layer. Moving outwards from the central, oldest layer, the
lens is split into an embryonic nucleus, the fetal nucleus, the adult
nucleus, and the outer cortex. New lens fibers which are generated from
the lens epithelium are added to the outer cortex (Bloemendal et al,
2004).
Anatomy of the anterior chamber of the eye

The anterior chamber of the eye is bounded anteriorly by the corneal inner surface, except at its periphery where it is related to the trabecular meshwork posteriorly, it is bounded by the lens within the papillary aperture, by the anterior surface of the iris and peripherally by the anterior face of the ciliary body (Figure(II)). The anterior and posterior boundaries meet at the drainage angle of the chamber (Nema et al, 1999).

The anterior chamber is communicated with the extracellular spaces of the iris, ciliary body and trabecular meshwork, and communicates through the papillary aperture with posterior chamber of the eye (Forrester et al, 2002).

Figure(II): A schematic diagram showing anatomy of the anterior chamber and drainage pathway of the aqueous humour (Bron et al, 1997).
The volume of the anterior chamber is about 220µl. This volume decreases by 0.11µl per year of life, but is 0.69µl larger per diopter of myopia (Spaeth et al., 1999).

The average anterior chamber depth is 3.15 (range 2.6 - 4.4) mm. The anterior chamber is deepest in the most central position, and shallowest towards the periphery. Its depth is decreased by 0.01 mm per year of life and is shallower in the hypermetropic eyes than in the myopic eyes; as the chamber deepens by 0.06 mm for each diopter of myopia. Depth is also decreased slightly during accommodation; partly by increased anterior lens curvature and partly by forward translocation of the lens. Both anterior and posterior boundaries of the anterior chamber are variably curved. The dome of the cornea varies relatively little in the normals, but the posterior surface of the angle may be anteriorly convex, flat or posteriorly concave. Because of this variable features, there are discrepancies between the depth of the anterior chamber and the width of the anterior chamber angle (Spaeth et al., 1999).

**Physiology of the crystalline lens and the anterior chamber of the eye**

The crystalline lens is considerably thick, almost spherical to increase the refraction of light. This difference compensates for the smaller angle of refraction between the cornea and watery medium, as they have almost similar refractive indices (Kardong, 2008).

The lens requires nourishment as it is metabolically active in order to maintain its transparency and growth. Compared to other tissues in the eye, the lens has considerably lower energy demands (Whikehar & David, 2003).
The lens epithelium, located in the anterior portion of the lens between the lens capsule and the lens fibers, has a simple cubical epithelium (Forrester et al, 1996). These cells regulate most of the homeostatic functions of the lens. As nutrients, ions and liquid enter the lens from the aqueous humor, Na+/K+ ATPase pumps in the lens epithelial cells pump ions out of the lens to keep and maintain appropriate lens volume and osmolarity, with equatorially positioned lens epithelium cells contributing most to this current. The activity of the Na+/K+ ATPases keeps water and current flowing through the lens from the poles and exiting through the equatorial regions (Candia, 2004).

**Stages of aqueous humor formation**

*Aqueous humor is formed in three stages:*

1. delivery of ions, water, proteins and metabolic fuel by the ciliary circulation.

2. diffusion and ultrafiltration from the capillaries into the stroma driven by the hydrostatic pressure, osmotic pressure and concentration gradients.

3. ionic transfer into the basolateral spaces between the non-pigmented epithelial cells followed by water movement down the resultant osmotic gradient into the posterior chamber. Due to the blood-aqueous barrier, the relative lack of protein in aqueous humor establishes a Starling equilibrium that opposes passive fluid movement across the epithelial bilayer, and so aqueous humor production is considered an active process that require the expenditure of metabolic energy. The presence of various receptors and second messenger systems in the ciliary epithelia, the ability of
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drugs to stimulate or inhibit aqueous humor formation, and the diurnal variation in aqueous humor production suggest that the rate of aqueous humor production is influenced by the neurohumoral milieu of the ciliary processes. *(Kiel, 1998)*

**Figure (III)** Overview of aqueous humor formation. (BF: ciliary blood flow; Pt: stromal tissue hydrostatic pressure; Pa: extraocular arterial pressure; VO2: mitochondrial oxygen consumption; Pe: ciliary capillary pressure; pc: capillary plasma oncotic pressure; pt: stromal tissue oncotic pressure; Pv: ciliary venous pressure; Ra: ciliary arterial resistance; Rv: ciliary venous resistance; pa: aqueous humor oncotic pressure; F: aqueous humor flow; Ptd Ins: phosphatidylinositol; Ins 1; 4;5 P3: inositol trisphosphate (2nd messenger for Ca²⁺ release); DAG: diacylglycerol (2nd messenger for protein kinase C activation); G: G protein complex; R: receptor; C: adenylate cyclase; Pase: phosphoinositidase; Gs: stimulatory G protein complex; Gi: inhibitory G protein complex; Rs: stimulatory receptor; Ri: inhibitory receptor; TJ: tight junction; GJ: gap junction; ATPase: Na/K ATPase; open circles with arrows: transporters / cotransporters / antiporters; arrows: movement via ionic channels or diffusion) *(Kiel, 1998; Kiel and Reitsamer, 2010).*
Pathogenesis of Posterior Capsular Opacification

Cataract is one of the common diseases of the lens and is the leading cause of visual impairment worldwide. The incidence is much expected to increase as the world population ages. Surgery and implantation of a synthetic intraocular lens (IOL) is the only treatment available. One of the common complications of modern cataract surgery is posterior capsular opacification (PCO) causing secondary vision impairment (Apple et al, 1992).

PCO is a multifactorial disease caused by residual lens epithelial cells (LECs) at the anterior surface of the posterior lens capsule after cataract surgery. In most cases, PCO does not become clinically relevant until months or years after surgery (Apple et al, 1992). Long-term development of PCO is explained by the extended survival and growth of these leftover LECs for more than 100 days in protein-free media (Wormstone et al, 1997). LECs proliferation, migration, epithelial–mesenchymal transition (EMT), collagen deposition, and lens fiber regeneration may all share to develop PCO. The resultant capsular changes may be associated with wrinkling, contraction, and matrix production and so leads to significant visual impairment (Marcantonio et al, 2000).

Normally no cells line the posterior capsule of the lens. Pathological cells that line the capsule in posterior capsular opacification are either epithelial cells or fibrocytes (Nagamato et al, 1992).

Proliferation:

The exact reason for the response of LECs, which leads to their proliferation and the subsequent PCO development, is not known. The removal of lens fiber mass during cataract surgery seems to alter the
local environment and so induce proliferation of LECs (Rakic et al, 1997).

Residual cortex may also promote proliferation of PCO. Besides LECs, melanocytes from the iris and cells released from the blood due to the breakdown of the blood aqueous barrier may also contribute to the primary proliferation of cells (Raj et al, 2007).

This inflammation response may be increased by the presence of a foreign material, that is, the IOL. The response of the LECs in the lens capsular bag is monitored by the autocrine system. In this system, the residual LECs themselves secrete various cytokines that control the development of PCO. The evidence of the autocrine system is based on the observation that LECs in culture maintain themselves in a protein-free medium. A variety of cytokines including fibroblast growth factor (FGF), platelets derived growth factor (PDGF), hepatocyte growth factor (HGF), epidermal growth factor (EGF), insulin like growth factor (IGF), transforming growth factor β (TGFβ), interleukin 1 and 6, have been shown to regulate the behavior of LECs in vitro, but little is known about their invivo effects that can lead to PCO (Wormstone, 2001).

Basic FGF (bFGF) in the aqueous humor of rabbits rises up after surgery and stimulates proliferation of LECs. TGFb concentration in rabbit aqueous humor decreases after the surgery and returns to the preoperative level after about 30 days (Wallentin et al, 1998). TGFβ induces epithelial mesenchymal transition (EMT) of LECs and then leads to production of extracellular matrix (ECM) (de Iongh et al, 2005).

It seems that the initial fall in TGFβ allows proliferation of LECs
due to the action of bFGF and other growth factors (Wormstone, 2001). In children, the higher density of the LECs and higher number of mitotically active cells will result in a higher growth potential (Pandey et al, 1999).

Migration:

The migration of LECs towards the posterior capsule and their subsequent attachment to the posterior capsule are facilitated by multiple cell attachment molecules present on the LECs. These molecules include various integrin subunits (Mathew et al, 2003), cell adhesion molecules (CAM) (Volk & Geiger, 1986) and hyaluronan receptor CD 44 (Saika et al, 1998). Gly-Arg-Gly-Asp-Ser-Pro (GRGDSP) RGD peptide inhibited cell attachment, and migration on laminin and fibronectin that have Arg-Gly-Asp (RGD) peptide sequences (Oharazawa et al, 2005). Matrix metalloproteinases (MMPs), which are a group of proteolytic enzymes, are important for cell migration and cell mediated contraction that follow wound healing (Wong et al, 2004).

Differentiation:

The LECs have the ability to undergo both normal and abnormal differentiation. The normal pre-planned differentiation of LECs can lead to the formation of pearl-like structures in the posterior capsule known as bladder cells (Ernest, 2003). They have a homogenously granular cytoplasm with pyknotic ormo nuclei and do not express aSMA (Kurosaka et al, 1996). The bladder cells are quite dynamic, show reorganization and even disappear within a time period (Neumayer et al, 2006).

The LECs of the equatorial zone are believed to have a greater
tendency to form these cells compared to the anterior LECs. The abnormal differentiation of LECs takes place in a form of EMT. TGF beta induces the EMT of LECs and FGF promotes the survival of TGF beta-affected cells (Symonds et al., 2006). The EMT of LECs leads to the formation of myofibroblast cells that are positive to aSMA (alpha smooth muscle actin). The formation of myofibroblast also takes place locally at the cut margin of the anterior capsule (Nishi et al., 1997).

The appearance of aSMA gives a retractile property to the cell, causes wrinkling of the posterior capsule, and forms fibrous PCO. The myofibroblasts secrete various forms of ECM proteins such as fibronectin, collagen type I, collagen type III, chondroitin sulphate, dermatan sulphate and keratan sulphate (Nishi et al., 1995) amongst others.

In addition to classic PCO, the postoperative LECs proliferation is involved in the pathogenesis of anterior capsule opacification/fibrosis (ACO) and inter-lenticular opacification (ILO) (Werner et al., 2002). The ILO develops after cataract surgery between 2 intraocular lenses (IOLs) that is placed in the capsular bag (Spencer et al., 2002). This is pronounced in eyes in which a continuous curvilinear capsular opening overlaps the IOL edge and peripheral anterior IOL surface (Obstbaum, 1998).
Types of PCO

The opacification takes one of two morphologic forms. One form composed of capsular pearls, which can consist of clusters of opacified, swollen epithelial "pearls" or clusters of posteriorly migrated equatorial epithelial (E) cells (Bladder or Wedl cells). It is probable that both LECs types may contribute to the fibrous form of opacification (Figure (IV)). Anterior epithelial (A) cells are probably important in the pathogenesis of fibrous PCO, since the primary type of response of these cells is to undergo fibrous metaplasia. Although the preferred type of growth of the equatorial epithelial (E) cells is in the direction of bloated, swollen, bullous-like bladder (Wedl) cells, these also can share to formation of the fibrous form of PCO by undergoing a fibrous metaplasia. This is a particularly common occurrence in cataracts in developing world settings where cataract surgery has been delayed for several years, and where posterior subcapsular cataracts have turned into fibrous plaques (Peng et al, 1998).
Figure (IV): Eyes showing various forms of capsular opacification. A, Extensive anterior capsule opacification; B, Mixed type of PCO with fibrous (arrow) and pearl type areas (asterisk); C, Fibrous form of posterior capsule opacification (arrow); D, Proliferative or pearl form of posterior capsule opacification (asterisk); E, Linear posterior capsule opacification (Raj et al, 2007).

In contrast to the lesions of the anterior (A cells) capsule that cause phenomena related to fibrosis, the E cells of the equatorial lens bow tend to form cells that can differentiate towards Elschnig pearls (Bladder cells) and cortex. Equatorial cells (E-cells) are also responsible for formation of a Soemmering's ring. The Soemmering's ring, a dumb-bell or donut shaped lesion that forms following any type of rupture of the anterior capsule, was first described in connection with ocular trauma. The pathogenetic basis of a Soemmering's ring is rupture of the anterior lens capsule with extrusion of nuclear and some central lens material. The extruded cortical remnants then transform into Elschnig pearls. It is not widely appreciated that a Soemmering's ring forms virtually every time
any form of ECCE is formed, whether manual, automated or with phacoemulsification. This material is derived from proliferation of the epithelial cells (E-cells) of the equatorial lens bow. These cells have the capability to proliferate and migrate to the posterior side across the visual axis, thereby opacifying the posterior capsule. Because the Soemmering's ring is a direct precursor to PCO, surgeons must strive to prevent its formation (Saxby et al, 1998).

**Figure (V)** Slit lamp retroillumination photograph of (a) right eye showing after cataract in the form of complete 360° Soemmering's Ring with stretched zonules and clear visual axis and (b) left eye showing dense 360° Soemmering's ring with annular fibrosis of the capsule with clear optical axis (Akal et al.2014).
Risk Factors of PCO

The incidence of PCO varies widely, depending on the age of the patient, history of intraocular inflammation, the presence of pseudoexfoliation before surgery, cataract surgery technique, IOL material, edge design, and diabetes mellitus which has been known historically as a definitive risk factor (Ebihara et al, 2006).

Other factors believed to predispose to PCO include young age, complicated or traumatic surgery, juvenile rheumatoid arthritis, retinitis pigmentosa and uveitis. These conditions have increased and prolonged intraocular inflammation in the postoperative period (Tassignon et al, 1998). These results were also reported by Tan and Chee in 1993 who added high myopia as a risk factor.

1- Age:

Worldwide, Decreased visual acuity induced by PCO is reported to occur in 25% to 45% of patients 2 to 5 years after surgery. PCO formation is age dependent, with lower incidence in older patients but high rates in young patients, especially children and infants. (Awasthi et al, 2009). PCO is a major problem in paediatric cataract surgery where the incidence was nearly 100% (Tassignon, 2007).

2- Type of Cataract:

A higher incidence of PCO is found in mature and hyper mature cataracts (Vasavada et al, 1997). Posterior capsular opacification is more likely to occur after posterior subcapsular cataract rather than a nuclear cataract. Posterior capsular cataract is more common in younger age group where the lens epithelium is active. However the relation between
the type of PCO and the type of cataract is not documented (Vasavada & Singh, 1999).

3-Diabetes Mellitus:

Eyes of diabetic patients have incompetent blood-aqueous barrier function and so are more liable to postoperative inflammation (Zaczek & Zetterstrom, 1999).

When compared with non-diabetic patients, diabetic patients had significantly more PCO rate after cataract surgery, but the systemic status of the diabetes and the stage of diabetic retinopathy do not seem to correlate with the degree of PCO (Hayashi et al, 2004).

A study by Kato et al in 2001 showed that diabetic patients are more prone to anterior capsule contraction and shrinkage of the anterior capsule opening following cataract surgery. these changes have been suggested to occur by deposition of fibronectin, fibrillin-1, and various types of collagen in addition to other protein of extracellular matrix (ECM) probably arising as a result of diabetic hypoxia. It has been reported that reproliferation of Elschnig pearls after Nd:YAG capsulotomy occasionally occurs in diabetic eyes (Jones et al, 1995).

4- Uveitis:

Although the higher rate of PCO in uveitis is primarily due to their younger age, a moderately increased independent risk of PCO from uveitis cannot be excluded (Dana et al, 1997).

5-Pseudoexfoliation Syndrome (PXF):

There is a higher incidence of PCO in patients with pseudoexfoliation syndrome. This may be due to associated impairment
of blood aqueous barrier (Kuchle et al, 1997). Intraoperative factors as poor dilatation and presence of posterior synechia may interfere with proper cortical cleaning, therefore allowing LECs to proliferate. Another factor is related to weak zonules that lead to increased capsular folds facilitating migration of LECs. Another theory suggests that the high incidence of PCO is related to the anterior chamber hypoxia that has a stimulatory effect on LECs (Zagorski et al, 1989).

6-Retinitis Pigmentosa:

Jackson et al in 2001 reported that the incidence of posterior capsular opacification is higher in cases of retinitis pigmentosa [RP].

7-Myopia:

Myopic eyes have been thought to elevate the risk of PCO; this probably occurs because IOL implantation was deferred in them, but a study of IOL implantation in myopic eyes showed that there is no association between the degree of myopia and the rate of PCO (Raj et al, 2007).

8-Myotonic Dystrophy:

The disruption of both the blood-retinal and blood-aqueous barriers in these patients with myotonic dystrophy lead to an increase in blood-derived cytokines in the aqueous humor of these eyes after cataract surgery, which results in increased activation of LECs with fibrosis and contracture of the anterior capsule (Rosa et al, 2009). Patients with myotonic dystrophy need multiple capsulotomies following cataract surgery due to PCO and progressive capsulorhexis contracture (Gjertsen et al, 2003).
9- Other factors:

The IOL type (material, design, optic size and edge, haptic design), proper hydrodissection and removal of cortical parts, anterior capsule polishing, in-the-bag fixation of the optic and the haptic IOL part and anterior capsulorhexis diameter and localization (Nixon et al, 2010).
Prevention of PCO

Measures to prevent capsular opacification can be classified into two categories. The first category is to minimize the number of retained LECs and cortex through cortical cleanup. The second strategy is to prevent the remaining LECs from migrating posteriorly. The optic and the edge of the IOL are critical in the formation of such a physical barrier (Pandey et al, 2004).

Worldwide research laboratories attempting to minimize the problem of PCO development are focusing on several strategies, including advancing surgical techniques, IOL designs, IOL materials, use of therapeutic agents and combination therapy (Figure (VI)). The use of cytotoxic agents have the risk of toxic effects on surrounding ocular tissues. Advances in surgical techniques, intraocular lens designs, and materials have reduced the PCO rate, but it is still a significant problem. (Awasthi et al, 2009).

![Figure (VI): Scheme of current strategies toward finding a safe, effective and less expensive way to eliminate PCO.](Awasthi et al, 2009).

A- Surgical Techniques:

The main two types of cataract surgery extraction performed by the ophthalmologists are phacoemulsification and conventional extracapsular
cataract extraction (ECCE). The small incision size used in phacoemulsification (2-3mm) allows sutureless wound closure. Phacoemulsification is the most commonly performed cataract procedure. ECCE utilizes a larger wound (10-12 mm) and therefore usually requires stitching, although sutureless ECCE is also in use. ECCE involves the removal of almost the entire natural lens while the posterior lens capsule is left intact to allow implantation of an intraocular lens *(Davidson et al, 2000)*.

**Combined surgery:**

There was no significant difference in long term PCO between phacotrabeculectomy and phacoemulsification in the study done by Shin and his colleagues. Intraoperative, adjunctive use of mitomycin C in the phacotrabeculectomy group in the overall patients was protective factors against PCO *(Shin et al, 2002)*.

Combined cataract and vitreoretinal surgery with intraocular air/SF6-gas tamponade leads to severe posterior capsular fibrosis in the early postoperative period. The capsular fibrosis is caused by accumulation of fibrin and proliferation of stimulating factors in the narrow space between intraocular lens and air/SF6-gas bubble *(Scharwey et al 1998)*.

- **Continuous curvilinear capsulotomy:**

  There is no doubt that continuous curvilinear capsulotomy can help to minimize PCO by rendering the secure in the-bag placement of an IOL. It is extremely important to create a well centered CCC of the correct size for the prevention of migrating LECs. The CCC edge should be smaller than the IOL optic and cover its margin. Any decentered
oversized CCC or incomplete CCC with a radial tear will result in the apposition of both capsules. Even though the area lies in a very limited circumference, the LECs migrate from the edge of the anterior capsule onto the posterior capsule causing PCO (Hayashi et al, 1997).

Comparing a small capsulorhexis of 4.5 to 5 mm to lie completely on the IOL optic or a large capsulorhexis of 6 to 7 mm to lie completely off the lens optic, Small capsulorhexis were associated with less wrinkling of the posterior capsule and less PCO than were large capsulorhexis. PCO after IOL implantation has a multifactorial pathogenesis. Small (4.5 to 5.0mm) capsulorhexis and capsular bag implantation of 5.5mm acrylic IOL are likely to reduce the PCO incidence when compared with the 6.0 to 7.0mm capsulorhexis (Aykan et al, 2003). Not allowing the anterior and posterior capsule to fuse around the lens edge appears to facilitate migration of LECs from the anterior capsule onto the posterior capsule, and behind the lens optic where fibrosis occurs (Coombes & Seward, 1999).

There was a trend for patients with large capsulorhexis to have greater anterior chamber flare and cell reading compared with those having small capsulorhexis, this is due to increased blood-aqueous breakdown in patient with large capsulorhexis caused by increased turbulence of infusion fluid in anterior chamber and lens fragments coming into contact with uveal tissue. In small capsulotomy, the anterior capsule act as a protective barrier keeping the fluid and fragments mainly in capsular bag and away from iris (Saika et al, 2014).

- **Hydrodissection enhanced cortical cleanup:**

  Davidson et al in 2000 suggested that near 100% removal of residual LECs at the time of cataract surgery may be necessary to prevent LECs
proliferation on the posterior capsule and development of PCO. Hydrodissection enhanced cortical cleanup after cataract surgery to remove retained/regenerative cortical material and cells has been shown to be important for PCO prevention (Peng et al, 2000).

This technique is modified by cleaning the residual cortex in the presence of a posterior chamber IOL, which protected the posterior capsule from disruption. These studies demonstrated that hydrodissection is an effective method for cortex removal, but it does not alone completely eliminate LECs. The rare complications of this technique are posterior capsule rupture and nuclear dislocation into the vitreous (Awasthi et al, 2009).

Peng et al in 2000 demonstrated the benefit of the barrier effect of the IOL optic in preventing LEC growth and suggested that it can be a second line of defense when cortical cleanup is incomplete.

Polishing of the posterior capsule:

The most effective way to exclude any form of after cataract is the complete removal of all LECs during cataract surgery (Meacock, 2000). Polishing can be done either mechanically or hydrodynamically. In mechanical polishing the tip of the irrigating cannula is modified into a sand blasted diamond tip mounted on the irrigation handle under high microscopic magnification then rubbing the posterior capsule gently. There are different models for the polishing cannula that differ in the quality, type and extension of the sand blasting (Buratto, 2006).

Hydrodynamic polishing depends on the force by which fluid comes out of the irrigating cannula. This force forms a positive pressure that will push the cortical residues and cells to remove them from the
posterior capsule \((Venkatesh \ et \ al, \ 2009)\).

- **Anterior Capsule Overlap Of IOL Optic:**

  When the size of the anterior capsulorhexis is larger than that of the IOL, there is a high incidence of fibrous PCO since the anterior epithelium remains opposed to the posterior capsule. It is believed that with a capsulorhexis smaller than the IOL optic the adhesion between the anterior capsule and the IOL optic keeps the anterior lens epithelium away from the posterior capsule. This would decrease the incidence of migration of the anterior LECs behind the IOL optic \((Tan \ & \ Chee, \ 1993)\). On the other hand it has also been suggested that a capsulorhexis larger than the IOL optic allows adhesion of the anterior and posterior capsules, forming a Soemmering’s ring. This could contain the cells and regenerative cortical matter, preventing LEC migration onto the visual axis \((Trivedi \ et \ al, \ 2002)\).

- **Primary posterior capsulorhexis:**

  The posterior capsule itself does not opacify but acts as a scaffold for cellular migration. Therefore a posterior capsulorhexis at the time of surgery may prevent the central opacification that may require postoperative Nd:YAG laser capsulotomy \((Masket, \ 1992)\).

  *Gimbel \ In \ 1994* suggested a posterior continuous circular capsulotomy in three situations:

  - To prevent extension of an inadvertent capsular tear.
  - The presence of posterior capsule plaque.
  - In infants because they usually develop PCO and usually they are not able to have posterior capsulotomy.
A 30 gauge unbent disposable needle is used to perforate the central part of the posterior capsule in front of the retrolental space of Berger. A small amount of viscoelastic is injected gently and slowly into the capsular bag hole to fill space of Berger. A delicate capsulorhexis forceps is used to tear the posterior capsule in the same way as anterior capsulorhexis. Although the posterior capsule is thinner than the anterior capsule, there is neither a nucleus nor zonular fibers to direct the tear towards the periphery. The size of PCCC should be smaller than the size of the implanted optic (Galand, 1999).

Intraoperative complication consisted of poorly controlled capsular tears, resulting into an over size or eccentric capsulotomy. Extension of the tear out to the capsular fornix is less frequent than with the anterior capsulorhexis (Galand et al., 1996). Postoperative complication includes opacification of the PCCC window. Roughly 10% of the cases develop Elschnig pearls or a fibrotic membrane in the window within 2 years. Diabetes mellitus and uveitis are risk factors for closure of PCCC (Tassignon et al., 1996).

The CCC is gold standard technique and has been used by many surgeons for pediatric cataract surgery in children after 2 years of age. On the other hand, it has been showed that vitrectorhexis technique is frequently used for anterior capsulectomy in pediatric cataracts because of the ease of performance in children younger than 2 years of age (Wilson, 2004). The anterior capsular opening is made by the vitrector probe which reaches anterior chamber through clear cornea or scleral tunnel (Figure VII), cataractous lens is removed by using bimanual irrigation and aspiration using bimanual irrigation and aspiration, then a posterior chamber foldable, acrylic, IOL was inserted through the incision. A sclerotomy was created at pars plicata or pars plana after
conjunctival incision. Then vitrector hand piece introduced into anterior vitreous via sclerostomy. Anterior vitrectomy was performed, then posterior vitrectorhexis was performed by using the vitrector hand piece. The main advantages of this technique are to ease both anterior and posterior capsulotomies and possibly the prevention of the development of PCO in pediatric cataract cases several advantages. Other advantages: First, the use of infusion for vitrectorhexis and usage of small amount of OVD only in IOL implantation may facilitate removal of inflammatory mediators and lead to less postoperative inflammation. Second, an anterior vitrectomy via posterior route after the implantation of IOL prevents the vitreous prolapse into the anterior chamber during the operation (İlhan et al, 2013).

Figure (VII) Anterior capsullectomy performed with a 25-gauge vitrector in a pediatric cataract (Caceres, 2006).

Combining primary posterior capsulorhexis (PPC) and posterior optic button holing in cataract surgery prevent after-cataract formation effectively and elevate postoperative stability of the IOL (Figure (VIII) (Stifter et al, 2007).
Figure (VIII) The PCCC was approximately 3 mm to 4 mm and smaller than the anterior capsulorrhexis (Vasavada et al, 2002).

❖ Posterior Capsulorhexis / Vitrectomy:

Posterior capsulorrhexis (PCCC) with posterior optic buttonholing (POBH) is a technique to prevent PCO that entails the performance of a 4.5-mm posterior capsulorrhexis and buttonholing a three-piece IOL behind it. The IOL forms a tight diaphragm with the posterior capsule, preventing LECs from gaining access to the retrolental space(Figure(IX ). This technique is effective for the management of posterior lens capsules and anterior vitreous in pediatric cataract surgery (Huang & Xie, 2009).

Figure(IX): Posterior optic buttonholing of a single piece intraocular lens. (Jones, 2012).
Postoperative inflammation and a traumatic surgery:

Pathological and Clinical examination have provided that proliferation of residual LECs are often related to the amount and duration of anterior segment inflammation both intra and postoperatively (Apple et al, 1992). A traumatic surgery, which is enhanced by small incision surgery, is therefore of a great importance. NSAIDs are effective in decreasing postoperative inflammation and also inhibit LEC proliferation (Nishi et al, 1995).

Prevention of capsular opacification in children:

PCO is even more threatening in young adults and children, with a higher incidence and greater amblyogenic effect and quicker incidence. The rates of PCO in children ranged from 43.7% to 100%, mainly because of the high proliferation of LECs (Wilson & JrTrivedi, 2007).

Different approaches have been used to prevent capsular opacification in children including:

- Capsular tension rings (CTRs) (Nagamoto & Bissen-Miyajima, 1994).
- Pars plana vitrectomy and lensectomy (Basti et al, 1996).
- Primary posterior capsulectomy with anterior vitrectomy (Plager et al, 1997).
- Posterior continuous curvilinear capsulorhexis with optic capture (Gimbel & DeBron, 1994).
- Primary posterior capsulectomy but without anterior vitrectomy (Fenton and O'Keefe, 1999).
- Capsular fusion (Hayashi et al, 2002).
- Vitrectorhexis (Wilson, 2004).
Capsular tension rings (CTRs)

Capsular tension rings are intraocular implantation devices that maintain post-operative capsular bag integrity and stabilize the capsular bag by reinforcing zonules in eyes with a weak zonular apparatus as in high myopia (Nagamoto & Bissen Miyajima, 1994). It inhibits PCO by separating the posterior and anterior capsular flaps which allow aqueous humor to circulate in and out of the capsular bag (Kavoussi et al, 2011), also CTRs may stretch the posterior capsule and prevent collapse of capsular bag resulting in decrease of the distance between the intraocular lens (IOL) and the posterior lens capsule. This may create a mechanical barrier together with the use of square edged IOLs that prevents LECs migration, So CTRs may have some influence on PCO formation (Menapace et al, 2000).

B- Role of Intraocular Lens in PCO Prevention:

A wide range of improvements has been introduced specifically to prevent PCO. Among these, several advancements have been made in IOL materials and designs to improve biocompatibility assessed in terms of the eye's foreign body reaction against the IOL (uveal biocompatibility) and interaction of the IOL with residual LECs within the capsular bag, which influences LECs migration, proliferation and EMT, resulting in anterior capsular opacification and PCO (capsular biocompatibility) (Werner, 2008).

Several experimental and clinical studies have been performed to demonstrate the role of the IOL designs and materials to decrease the incidence of PCO. Comparison of hydrophobic and hydrophilic materials showed that the type of material might influence PCO development (Schmidbauer et al, 2002).
Although it is well recognized that a hydrophilic acrylic material is more biocompatible (Hollick et al, 1999), IOLs made of this material have been shown to support LECs migration, adhesion and proliferation and thus PCO development (Tognetto et al, 2002) compared with an IOL made of polymethylmethacrylate (PMMA) or hydrophobic acrylic materials (Hayashi et al, 2001). Modification of the IOL surface, which can inhibit cell and protein adhesion, has been suggested as one of the most tolerable methods for preventing PCO because it does not require any manipulation within the eye or the use of any harmful or active agents during IOL implantation. Surface modifications of PMMA IOLs by carbon and titanium (Yuan et al, 2004), and polytetrafluoroethylene (Werner et al, 1999) and of silicon IOLs by oxygen and carbon dioxide plasma (Hettlich et al, 1991) or a sulfonate and carboxylate group containing polymer (Yammine et al, 2005) have been reported to have higher biocompatibility and effectiveness in prevention of PCO. Recently, IOL surface modification by polyethylene glycol and gas plasma has been shown to influence LECs behavior and to prevent PCO (Sinha et al, 2013).

A higher PCO inhibitory effect has been observed with IOLs that provide a mechanical barrier effect on the posterior lens capsule (Hollick et al, 1999). Nishi et al in 2002 demonstrated that the sharp edge optic IOL and the formation of a capsular bend are highly effective in reducing PCO rate. Adhesion of the IOL material with the lens capsule also plays a role in PCO prevention by creating a sharp capsular bend (Linnola et al, 2000), which inhibits LECs migration onto the posterior capsule. Nishi and other investigators in 2007 also demonstrated that contact inhibition of migrating LECs is induced at the capsular bend which leads to PCO prevention.
The edge of any optic might provide a barrier to ingrowth of unaltered epithelial cells, despite proliferation into pearl formation outside the optic edge. The effect of a square edged optic design as a barrier was first discussed by Nishi et al in 2001 (Figure (X)). The tighter the stretching of the posterior capsule, the greater is the barrier effect. This is best seen with convex posterior or biconvex optics supported by angulated haptics. Convex anterior lenses, which are plano-posterior do not stretch the capsule in the same way as convex posterior IOL do and so considered with a higher incidence of epithelial proliferation (Nishi & Nishi, 2003).

Figure (X): Blocking of LEC migration at posterior sharp optic edge due to bending of the capsule (left) compared to round edge IOL (right) (Nishi, 1999).
Lasergap (laser ridge) lenses are made to expose a space between the back of the IOL and the posterior capsule. This may be achieved by either a complete circumferential ridges, or incomplete with bosses or a meniscus (concave posterior) lens. Although this design helps to protect the IOL during laser capsulotomy, it is associated with higher incidence of PCO (Agarwal, 2000).

The biconcave minus-power IOL, which has a thicker, square, truncated optic edge with a ridge that encircles the periphery of the optic for 360 degree, appears to have an enhanced barrier effect, especially at the optic haptic junction. This further decreases the ingrowths of migrating LECs toward the visual axis (Vargas et al, 2003).

The sharp posterior optic edge design of certain IOLs (as Sensar OptiEdge IOL) lead to significantly less PCO rate postoperatively (Buehl et al, 2005). The anterior edge design appeared to have no preventive effect and most results confirm that a sharp posterior optic or capsular bend formation is the main factor in preventing PCO (Nishi et al, 2004).

On the other hand, sharp edged IOLs can lead to an increased incidence of persistent edge glare phenomenon (Ellis, 2001). Intraocular lenses with a rectangular edge cause the light rays that are refracted through the peripheral IOL to be more intense on the peripheral retina, Round edged IOLs disperse the light rays over a larger surface area of the retina leading to less glare (Buehl et al, 2005).

The single piece acrysoft IOL was designed to have a square (truncated) edge of the optic that had a matte (velvet or ground glass) appearance, a feature that may decrease edge glare and other visual phenomena (Pandey et al, 2004).
Haptic design:

In addition to the optic edge, it has been noticed that the haptic angulation (Figure (XI) also minimizes the incidence of PCO by inducing a pressure gradient over the posterior capsule \cite{Ayaki et al, 2003}.

The lens is designed to:-

- Keep the anterior IOL optic surface away from the anterior capsule to improve its transparence.
- Have the effect of a complete capsular tension ring.
- Prevent PCO \cite{Werner et al, 2004}.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{haptic_angulation.png}
\caption{Haptic angulation \cite{Findl et al, 2005}.}
\end{figure}

The PCO preventive effect of sharp edge optics suggests that it may be useful to maximize the barrier effect to migrating LECs at the posterior optic edge by pushing the IOL backward against the posterior capsule. This can be achieved with angulated haptic designs. They were originally introduced because an angulation reduced iris shave in cases where the lens was placed in the sulcus. Consequently, such posterior vaulting characteristics can be found in many modern three piece IOLs, with angulation of 5 to 10 degrees \cite{Findl et al, 2005}.
The IOL material:

PCO is significantly higher in the PMMA IOLs compared to the Acrylic and silicone IOLs: acrylic (with an incidence of 17 %), silicone (18%), and PMMA (36 %) (Yoshida et al, 2002).

While another study showed that the rate of Nd:YAG laser capsulotomy was the lowest in the hydrophobic acrylic group (7.1%), followed by silicone (16.2%), PMMA (19.3%) and hydrophilic acrylic (31.1%), respectively. A low incidence of PCO and Nd:YAG laser treatment was detected in hydrophobic acrylic IOLs in comparison to other three types of IOLs implanted (Auffarth et al, 2004).

In patient with silicone IOL, significant PCO was more common if there was concurrent ocular disease, while with the acrylic IOL concurrent ocular disease did not seem to elevate the risk of PCO (Pohjalainen et al, 2002).

It has been shown that the acrylic IOLs (centerflex and acrysof) had lower CPCO (central PCO) and PPCO (peripheral PCO) scores than the silicon plate IOL. There was no significant difference in Soemmering's ring formation among the three models. Pathological evaluations revealed effective blockage of migrating LECs at the site of the truncated optic edge of the Centerflex and Acrysof IOLs. Even in the presence of large amounts of retained / regenerative cortical material (Vargas et al, 2002). However IOL design seems to be of more important role in preventing PCO than the material used as silicone and hydrophobic acrylic IOLs of rectangular sharp optic edges are similarly effective in inducing the PCO inhibiting effect. Three years after surgery, the PCO intensity and the YAG rate were low with both IOL models (Findl et al, 2005).
IOLs made of hydrogel were associated with a significantly higher degree of PCO and more laser capsulotomies than PMMA and silicone intraocular lenses (Hollick et al, 2000).

**Multifocal IOLs:**

There are either refractive or diffractive. Patients with diffractive IOLs showed an incidence of PCO of about 55.6% (Slagsvold, 2000).

Therefore multifocal design shows a higher incidence of PCO especially the diffractive ones when compared to monofocal IOLs (Auffarth et al, 2001).

The following table shows the rate of Nd:YAG laser capsulotomy on 8 different IOL types which was held in the Department of Ophthalmology and Visual Sciences, University of Utah, USA in the period between January 1, 1988 – July 31, 2002 (with the total number of pseudophakic eyes, N=7523 obtained postmortem). It has been noted that the 2 rigid optic designs had the highest rate but one of the important limitations in this study was lack of detailed information such as dates of IOL implantation or the time between implantation and death (Pandey et al, 2004).
Table (I) the rate of YAG capsulotomy with different forms of IOLs (Pandey et al, 2004).

<table>
<thead>
<tr>
<th>IOL</th>
<th>YAG%</th>
</tr>
</thead>
<tbody>
<tr>
<td>All lenses</td>
<td>28.1%</td>
</tr>
<tr>
<td>Foldable lenses</td>
<td>15.6%</td>
</tr>
<tr>
<td>Rigid lenses</td>
<td>30.9%</td>
</tr>
<tr>
<td>3PC Silicone PMMA</td>
<td>12.2%</td>
</tr>
<tr>
<td>3PC Acrylic PMMA (Acrysof)</td>
<td>4.7%</td>
</tr>
<tr>
<td>1 PC Silicone plate (large hole)</td>
<td>20.2%</td>
</tr>
<tr>
<td>3 PC Silicone Polymide</td>
<td>22%</td>
</tr>
<tr>
<td>1 PC Silicone plate (small hole)</td>
<td>23.2%</td>
</tr>
<tr>
<td>3 PC Silicone Prolene</td>
<td>23.7%</td>
</tr>
<tr>
<td>3 PC PMMA (Rigid)</td>
<td>30%</td>
</tr>
<tr>
<td>1 PC All PMMA (Rigid)</td>
<td>31.5%</td>
</tr>
</tbody>
</table>

**Site of implantation:**

**In the bag IOL Fixation:**

In the bag fixation of the optic and the haptic is required to consistently decrease the incidence of central PCO. Tan and associates in 1993 noticed an elevated incidence of fibrosis type PCO in cases of ciliary sulcus fixation. In the bag fixation is facilitated by creating a continuous curvilinear capsulorhexis. It functions primarily to enhance
the IOL optic barrier effect *(Peng et al, 2000)*. In the bag fixation, along with other measures related to surgical techniques and IOL choice, have decreased the incidence of Nd: YAG laser posterior capsulotomy to 0.9% with AcrySof IOL *(Schmidbauer et al, 2002)*.

*(Menapace, 2006)* studied the efficacy of posterior optic buttonholing (POBH) through a primary posterior capsulorhexis to preserve full capsular transparency, and its potential as a routine alternative to standard in the bag implantation of sharp edged optic IOLs. POBH precluded LECs from accessing the retrolental space. The sandwiched posterior capsule blocked optic contact, thereby resulting in fibrosis of the anterior capsule. POBH prevented after-cataract independent of the optic edge design.

**Bag in the lens (BIL) technique:**

The bag in the lens (BIL) intraocular implant is an alternative approach to standard lens in the bag cataract surgery. The lens is supported by anterior and posterior capsulorhexis, which confers a number of benefits in terms of lens centration, rotational stability and prevention of PCO *(Lauwers et al, 2013)*.

The risk for retinal detachment compared with the lens in the bag implantation is decreased. However, since no Nd:YAG laser capsulotomy is necessary after BIL technique, the risk for retinal detachment after BIL is lower with time *(Tassignon, 2008)*.

The BIL technique consists of implanting a lens that is round. The 5 mm optic is surrounded by a peripheral groove with elliptical haptics (figure 1V). The haptics are perpendicular to one another, allowing for accommodation of both the anterior and posterior capsulorhexis. That
means a very precise-sized anterior and posterior capsulorhexis is needed. During surgery, a carefully centered 5 mm hole is created in the anterior capsule. After the crystalline lens is extracted, a matching 5 mm hole is created in the posterior capsule. When the BIL is positioned into place, the posterior haptics slide under the posterior capsule and the anterior haptics rest on top of the anterior capsule (Figure(XII)). The end result is that the BIL implant sandwiches the two layers of capsule and seals the LECs in the interhaptic groove (Tassignon, 2011).

**Figure(XII)** Structure and profile of the BIL intraocular implant (Tassignon & assignee, 2000).
Treatment of Posterior Capsular Opacification

Patients who developed PCO are treated by either YAG laser capsulotomy or surgical capsulotomy (Chelliah & Sowmiya, 2015).

Neodymium: yttrium-aluminum-garnet (Nd:YAG) laser capsulotomy is the most common and effective treatment for clinically significant PCO (Duman et al., 2015). With recent techniques and IOLs, the expected rate of PCO and following Nd: YAG laser posterior capsulotomy rate is diminished to less than 10% (Apple et al., 2001).

A. Laser treatment:

Nd: YAG laser capsulotomy is noninvasive and fast procedure with immediate improvement. Although, it is noninvasive and considered safer than surgical approach it can lead to some complications (Karahan et al., 2014). PCO-induced visual affection can be treated by Nd:YAG laser capsulotomy by formation of an opening in the posterior capsule and thus avoiding distortion of light in its passage (Figure (XIII) (Wormstone et al., 2009).

Despite different modalities of surgical techniques, intraocular lens material or design, implantation of additional devices, and pharmacological interventions, PCO remains the most frequent long term complication after cataract surgery (Findl et al., 2007).
Figure (XIII) The YAG laser being used to create an opening in the posterior capsule (McKellar, 2015).

**Indications:**

*Clinically significant PCO requiring Nd:YAG laser treatment has the following criteria:*

- diminished visual acuity by 2 lines compared with best corrected visual acuity early in the postoperative period. Visual symptoms do not always correlate to the observed amount of PCO. Some patients with significant PCO on slit lamp examination are relatively asymptomatic while others have significant symptoms with mild apparent haze, which is reversed by capsulotomy (Cheng et al, 2001).

- PCO which is seen against the red reflex by ophthalmoscopy examination.

- PCO which is visible within the central area of the pupil seen at the slit lamp, fibrosis and / or Elschnig pearl formation.

- Glare or decreased contrast sensitivity (Sundelin & Sjostrand, 1999).
Contraindications:

\textit{Nd:YAG laser capsulotomy is contraindicated if:}

- Corneal scars, edema or irregularity that makes a barrier against adequate visualization of the target aiming beam or degrade the Nd:YAG laser beam optics, preventing reliable and predictable optical breakdown.

- If a glass IOL is involved due to the possibility of a complete fracture in the glass optic. The merits of surgical discussion should be carefully weighed (Figure (XIV)).

- Suspected or known active cystoid macular edema (CME), given evidence regarding a beneficial effect of the barrier function of an intact posterior capsule and rare cases of clinical CME that occur after Nd:YAG laser capsulotomy. Avoidance of capsulotomy in an eye with active inflammation is suggested until the visual impairment becomes unacceptable to the patient.

- Nd:YAG laser posterior capsulotomy may be complicated by a retinal tear or detachment. Clinical data that has a correlation between the energy level of laser pulses and retinal detachment is lacking.

For eyes that have high risk for retinal detachment, the least amount of energy and the lowest possible number of shots should be used to perform the capsulotomy, and only a small opening is advised to be made (Table (II). Repolishing the capsule may be considered in high-risk patients (Roger & Steinert, 1985).

**Table (II):** Contraindications to laser capsulotomy *(Roger & Steinert, 2013).*

<table>
<thead>
<tr>
<th>Absolute Contraindications</th>
<th>Relative Contraindications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corneal scars, edema or irregularities that interfere with target visualization or make optical breakdown unpredictable.</td>
<td>Glass intraocular lens.</td>
</tr>
<tr>
<td></td>
<td>suspected or Known cystoid macularedema</td>
</tr>
<tr>
<td>Inadequate stability of the affected eye.</td>
<td>Active ocular inflammation.</td>
</tr>
<tr>
<td></td>
<td>increased risk for retinal detachment.</td>
</tr>
</tbody>
</table>

**Figure (XIV)** The glass IOL by Lynell Optics worked well but could break with YAG laser treatment. The polyamide haptics are used in the haptic structure of some modern silicone lenses *(Fritch, 1984).*

The capsulotomy is made no sooner than 6 months postoperatively, the capsular opening should be small (2mm in diameter) but perfectly aligned relative to the pupil and the IOL, laser pulses should have low energy and be posteriorly defocused, when energy higher than 2mj is required, the capsulotomy is performed by applying punctures in a circular pattern instead of a cruciate pattern (in order to spare the visual axis in the case of IOL pitting) *(Stefanescu-Dima et al, 2003).*
Complications:

1- Increased IOP:

One of the most common complication of posterior capsulotomy is transient increase of the IOP which can be explained by deposition of debris in the trabecular meshwork, (Gore, 1994) pupillary block, (Parker et al, 1984) and inflammatory swelling of the ciliary body or iris root associated with angle closure (Ruderman et al, 1983).

2- IOL damage or pitting:

Usually not visually significant. (Newland et al, 1999).

3- Retinal Detachment

Factors postulated as predisposing to retinal detachment after capsulotomy include the amount of power delivered, preexisting retinal or vitreous disease, axial myopia and a history of retinal detachment in the fellow eye (Ficker et al, 1987). Retinal detachment incidence is higher if laser capsulotomy is done within the first 3 months after surgery (Masket, 1992). It has been suggested that longer the interval between cataract surgery and capsulotomy, the lower the risk of retinal complication (Bukelman et al, 1992).

4- Cystoid macular edema (Shani et al, 1994).

5- Corneal edema (Roger & Steinert, 2013).

6- Macular holes (Chaudhary et al, 1999).

7- Iritis (Khanzada et al, 2008).
8- Endophthalmitis *(Carlson & Koch, 1988).*

9- IOL Movement and Refractive Changes:

Due to backward movement of the IOL resulting in hyperopic shift which is usually mild and visually insignificant *(Findl et al, 1995).*

**B. Surgical Treatment:**

Surgical posterior capsulotomy is a safe and effective procedure in experienced hands and could replace YAG laser *(Wahab et al, 2011).* Although primary posterior capsulotomy and and anterior vitrectomy is standard care for children to avoid multiple surgeries for PCO, but PCO may not be avoided thoroughly *(Yao et al, 2002).* Management of PCO in infants and young children is always complex than in adults. ND:YAG laser capsulotomy is not always effective especially for children with thick PCO *(Xie & Huang, 2008).* Because visual rehabilitation after surgery may lead to amblyopia, early visual rehabilitation by creating an adequate and clear visual axis is an important step in management of pediatric cataract *(Koller, 2000).*

Surgical removal of membrane can be achieved via an anterior approach through the limbus, but there will a risk of IOL destabilization. Some surgeons recommend adopting 25-gauge transconjunctival sutureless virectomy through a two-port pars plana *(Lam et al, 2005).*

A neodymium: YAG (Nd: YAG) laser capsulotomy is usually inadequate in children since reformation of the opacification is found months later in these eyes with high reaction and also due to inadequate stability of the eye *(O’Keefe et al, 2001).*
Complications:

As this procedure is a surgical procedure, it carries the risks of surgery, this include:

- Endophthalmitis
- Complication of anesthesia
- Retinal detachment (Agarwal, 2000).
- Cystoid macular edema
Patients and Methods

Type of study

Prospective cross sectional study: compares anterior chamber depth in pseudophakic patients with posterior capsular opacification before and after Nd:YAG laser treatment.

Study site

The study was conducted at ophthalmology department, Benha University Hospital.

Study population

- An informed written consent was taken from each patient participated in this study.
- The study included 19 eyes (4 eyes of male patients and 15 eyes of female patients).
- The patients underwent previous phacoemulsification with implantation of foldable one-piece intraocular lens complicated by posterior capsular opacification (PCO).
- Posterior capsulotomy was performed after at least one year by the same surgeon with Nd:YAG laser using Zeiss VisuLAS YAG III device and by contact lens (Abraham capsulotomy lens).
- The energy level, total spot count and total energy use of each patient were recorded.
- All study patients received a standard medical regimen after laser (0.1% brimonidine eye drop, one drop immediately after laser; and fluorometholone eye drop four times a day for 1 week).
Patients and methods

• Refraction of each patient was recorded before laser treatment, after 1 week, one month and 3 months after the procedure.
• Anterior chamber depth was assessed in all patients before laser treatment then 1 week, one month and 3 months after treatment.
• A-scan ultrasound will be used to assess the anterior chamber depth.
• The same intended energy of the laser (0.8 mJ/spot) and size of the posterior capsulotomy were used for every patient (average size: 5 mm) which required total energy (15-26mJ). The mean total energy power delivered was 20 ± 3.00 mJ.

Inclusion criteria

• Pseudophakic patients with foldable one piece IOL who had posterior capsular opacification needing (Nd:YAG) laser for its treatment with a minimum duration of 3 months between the cataract surgery and the YAG-capsulotomy.
• Patients above 40 years old.
• Both gender.

Exclusion criteria

• Patients that had Complications during cataract surgery or during the post operative period as well as patients who can not maintain an upright position during the procedure.
• Patients with history of previous ocular surgery such as glaucoma or combined surgery, history of ocular trauma or corneal opacity.
**Statistical methods**

Data management and statistical analysis were done using SPSS vs.25. Numerical data was summarized as means and standard deviations. Categorical data was summarized as numbers and percentages. Parameters were compared at baseline, one week, one month and three months using Friedman’s test. Comparisons between baseline and three months were done using Wilcoxon signed rank test. All P values were two sided. In multiple comparisons, P values were adjusted using Bonferroni’s method. P values less than 0.05 were considered significant.
- Our study included 19 eyes.

- There were 3 male patients, one of them was included for both eyes and 13 female patients, 2 of them were included for both eyes so we had 4 eyes belonged to male patients and 15 eyes belonged to female patients.

Table (1) shows sex, age, interval between cataract surgery and capsulotomy and total energy delivered.

<table>
<thead>
<tr>
<th>Sex</th>
<th>Age (years)</th>
<th>Interval between cataract surgery and capsulotomy (years)</th>
<th>Total energy delivered (mj)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>55</td>
<td>4</td>
<td>17</td>
</tr>
<tr>
<td>Female</td>
<td>48</td>
<td>1</td>
<td>16</td>
</tr>
<tr>
<td>Female</td>
<td>60</td>
<td>3</td>
<td>20</td>
</tr>
<tr>
<td>Male</td>
<td>78</td>
<td>5</td>
<td>18</td>
</tr>
<tr>
<td>Male</td>
<td>78</td>
<td>5</td>
<td>22</td>
</tr>
<tr>
<td>Female</td>
<td>70</td>
<td>1</td>
<td>15</td>
</tr>
<tr>
<td>Female</td>
<td>70</td>
<td>1</td>
<td>19</td>
</tr>
<tr>
<td>Female</td>
<td>67</td>
<td>4</td>
<td>21</td>
</tr>
<tr>
<td>Female</td>
<td>50</td>
<td>1</td>
<td>23</td>
</tr>
<tr>
<td>Female</td>
<td>50</td>
<td>1</td>
<td>16</td>
</tr>
<tr>
<td>Male</td>
<td>55</td>
<td>5</td>
<td>20</td>
</tr>
<tr>
<td>Female</td>
<td>57</td>
<td>6</td>
<td>24</td>
</tr>
<tr>
<td>Female</td>
<td>65</td>
<td>2</td>
<td>26</td>
</tr>
<tr>
<td>Male</td>
<td>67</td>
<td>7</td>
<td>19</td>
</tr>
<tr>
<td>Female</td>
<td>54</td>
<td>7</td>
<td>18</td>
</tr>
<tr>
<td>Female</td>
<td>60</td>
<td>17</td>
<td>25</td>
</tr>
<tr>
<td>Female</td>
<td>55</td>
<td>6</td>
<td>26</td>
</tr>
<tr>
<td>Female</td>
<td>55</td>
<td>4</td>
<td>22</td>
</tr>
<tr>
<td>Female</td>
<td>60</td>
<td>5</td>
<td>19</td>
</tr>
</tbody>
</table>
Table (2) shows anterior chamber depth, spherical equivalent (SE), intraocular pressure of the patients before capsulotomy, after 1 week, after one month and after 3 months.

<table>
<thead>
<tr>
<th>Patient</th>
<th>ACD</th>
<th>SE</th>
<th>IOP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before capsulotomy</td>
<td>After 1 week</td>
<td>After 1 month</td>
</tr>
<tr>
<td>Patient (1)</td>
<td>4.10</td>
<td>4.23</td>
<td>4.34</td>
</tr>
<tr>
<td>Patient (2)</td>
<td>4.48</td>
<td>4.50</td>
<td>4.45</td>
</tr>
<tr>
<td>Patient (3)</td>
<td>3.24</td>
<td>3.28</td>
<td>3.27</td>
</tr>
<tr>
<td>Patient (4)</td>
<td>4.07</td>
<td>4.22</td>
<td>4.13</td>
</tr>
<tr>
<td>Patient (5)</td>
<td>4.15</td>
<td>4.14</td>
<td>4.14</td>
</tr>
<tr>
<td>Patient (6)</td>
<td>3.77</td>
<td>3.88</td>
<td>3.92</td>
</tr>
<tr>
<td>Patient (7)</td>
<td>4.12</td>
<td>4.14</td>
<td>3.81</td>
</tr>
<tr>
<td>Patient (8)</td>
<td>3.58</td>
<td>3.30</td>
<td>3.60</td>
</tr>
<tr>
<td>Patient (9)</td>
<td>4.01</td>
<td>3.78</td>
<td>3.78</td>
</tr>
<tr>
<td>Patient (10)</td>
<td>3.60</td>
<td>3.63</td>
<td>3.51</td>
</tr>
<tr>
<td>Patient (11)</td>
<td>4.32</td>
<td>3.65</td>
<td>3.79</td>
</tr>
<tr>
<td>Patient (12)</td>
<td>4.76</td>
<td>4.78</td>
<td>4.78</td>
</tr>
<tr>
<td>Patient (13)</td>
<td>4.68</td>
<td>4.58</td>
<td>4.59</td>
</tr>
<tr>
<td>Patient (14)</td>
<td>4.67</td>
<td>4.68</td>
<td>4.70</td>
</tr>
<tr>
<td>Patient (15)</td>
<td>3.72</td>
<td>3.76</td>
<td>3.75</td>
</tr>
<tr>
<td>Patient (16)</td>
<td>4.04</td>
<td>4.03</td>
<td>4.05</td>
</tr>
<tr>
<td>Patient (17)</td>
<td>4.11</td>
<td>4.07</td>
<td>3.66</td>
</tr>
<tr>
<td>Patient (18)</td>
<td>4.36</td>
<td>4.38</td>
<td>4.34</td>
</tr>
<tr>
<td>Patient (19)</td>
<td>4.45</td>
<td>4.39</td>
<td>4.46</td>
</tr>
</tbody>
</table>
Patients' data
**Age and Gender**

Table (3) shows age and sex distribution of the studied group.

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Mean ±SD</th>
<th>60 ± 9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>Number (percentage %)</td>
<td>3 (19%)</td>
</tr>
<tr>
<td>Females</td>
<td>Number (percentage %)</td>
<td>13 (81%)</td>
</tr>
</tbody>
</table>

This study included 3 male patients (one of them was included for both eyes) and 13 female patients (2 of them were included for both eyes). The mean age was 60 ± 9 years.

![Figure (1) shows sex distribution of the studied group.](image)

Table (4) shows the mean and range of the Interval between cataract surgery & Nd-Yag capsulotomy (years).

<table>
<thead>
<tr>
<th>Interval between cataract surgery &amp; Nd-Yag capsulotomy (years)</th>
<th>Mean ± SD (years)</th>
<th>Range (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4 ± 4</td>
<td>(from 1 to 17 years)</td>
</tr>
</tbody>
</table>

The mean was 4 ± 4 years and the range from 1 to 17 years.
Table(5) shows the mean of total energy delivered to the studied group.

<table>
<thead>
<tr>
<th>Total energy delivered (mj)</th>
<th>Mean ± SD (mj)</th>
<th>Range (mj)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 ± 3.00</td>
<td>From 15 to 26</td>
<td></td>
</tr>
</tbody>
</table>

the mean was 20 ± 3.00 mj and the range From 15.00 to 26.00 mj. We used the circular pattern in the procedure.
Anterior chamber depth results

Table (6) shows the mean anterior chamber depth along follow up periods.

<table>
<thead>
<tr>
<th></th>
<th>Mean ± SD</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACD before capsulotomy (mm)</td>
<td>4.12 ± 0.41</td>
<td>0.870 (overall)</td>
</tr>
<tr>
<td>after 1 week ACD (mm)</td>
<td>4.07 ± 0.43</td>
<td>1.0</td>
</tr>
<tr>
<td>ACD after 1 month (mm)</td>
<td>4.06 ± 0.43</td>
<td>1.0</td>
</tr>
<tr>
<td>ACD after 3 months(mm)</td>
<td>4.04 ± 0.43</td>
<td>1.0</td>
</tr>
</tbody>
</table>

The overall P value shows no statistically significant value in any pair.

Before vs. 1 week (P = 1.0), Before vs. 1 month (P =1.0), Before vs. 3 months (P = 1.0).

Figure(2) shows mean anterior chamber depth along follow up periods.
Table (7) shows the number and percentage of the patients with increased and decreased ACD respectively.

<table>
<thead>
<tr>
<th>ACD status</th>
<th>Number</th>
<th>Percentage %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased</td>
<td>8 eyes</td>
<td>42.10%</td>
</tr>
<tr>
<td>Decreased</td>
<td>11 eyes</td>
<td>57.90%</td>
</tr>
</tbody>
</table>

In this study we had 8 eyes that had increased ACD and 11 eyes with decreased ACD after 3 months.

Figure (3) shows the percentage of the ACD change.
In those patients who had increased ACD after 3 months (8 eyes):

**Table (8)** shows the mean ACD in the patients with increased ACD.

<table>
<thead>
<tr>
<th>ACD (mm)</th>
<th>Mean ± SD</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>after 3 months</td>
<td>4.12 ± 0.37</td>
<td>0.012</td>
</tr>
<tr>
<td>before capsulotomy</td>
<td>4.05 ± 0.37</td>
<td></td>
</tr>
</tbody>
</table>

In this group the P value has significant value (0.012).

![Figure (4)](image)

Figure (4) shows the mean ACD in the patients with increased ACD.
In those who had decreased ACD after 3 months (11 eyes):

Table(9) shows the mean ACD in the patients with decreased ACD.

<table>
<thead>
<tr>
<th>ACD (mm)</th>
<th>Mean ± SD</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>before capsulotomy</td>
<td>4.17 ± 0.45</td>
<td>0.003</td>
</tr>
<tr>
<td>after 3 months</td>
<td>3.98 ± 0.48</td>
<td></td>
</tr>
</tbody>
</table>

In this group the P value has significant value (0.003).

Figure (5) shows the mean ACD in the patients with decreased ACD.
**Results**

**Axial length distribution of the studied group**

Table (10) shows the axial length distribution of the studied group.

<table>
<thead>
<tr>
<th></th>
<th>Mean ± SD</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>AXL before capsulotomy (mm)</td>
<td>22.61 ± 2.10</td>
<td>0.19 (overall)</td>
</tr>
<tr>
<td>AXL after 1 week (mm)</td>
<td>22.64 ± 2.11</td>
<td>0.26</td>
</tr>
<tr>
<td>AXL after 1 month (mm)</td>
<td>22.60 ± 2.11</td>
<td>1.0</td>
</tr>
<tr>
<td>AXL after 3 months (mm)</td>
<td>22.62 ± 2.10</td>
<td>0.07</td>
</tr>
</tbody>
</table>

The overall P value shows no significance (0.197).

Before vs. 1 week (P = 0.26), Before vs. 1 month (P = 1.0), Before vs. 3 months (P = 0.07).

**Figure (6)** shows the axial length distribution of the studied group.
Spherical Equivalent distribution of the studied group

Table (11) shows the spherical Equivalent distribution of the studied group.

<table>
<thead>
<tr>
<th></th>
<th>Mean ± SD</th>
<th>Range</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SE before Capsulotomy</td>
<td>-1.22 ± 2.189</td>
<td>From -5.5 to +2.5</td>
<td>0.792 (overall)</td>
</tr>
<tr>
<td>SE after 1 week</td>
<td>-0.83 ± 1.62</td>
<td>From -6 to +1.375</td>
<td>1.0</td>
</tr>
<tr>
<td>SE after 1 month</td>
<td>-0.69 ± 1.54</td>
<td>From -5.37 to +1.5</td>
<td>1.0</td>
</tr>
<tr>
<td>SE after 3 months</td>
<td>-0.86 ± 1.59</td>
<td>From -5.37 to +1.25</td>
<td>1.0</td>
</tr>
</tbody>
</table>

The overall P value shows no significant value (0.792).

Before vs. 1 week (P = 1.0), Before vs. 1 month (P =1.0), Before vs. 3 months (P = 1.0).

Figure(7) shows the spherical Equivalent distribution of the studied group.
spherical Equivalent in those patients who had increased ACD after 3 months (8 eyes):

Table (12) shows the spherical Equivalent distribution of the patients who had increased ACD.

<table>
<thead>
<tr>
<th>SE</th>
<th>Mean ± SD</th>
<th>Range</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>before Capsulotomy</td>
<td>-1.23 ± 2.35</td>
<td>From -5.5 to +1.87</td>
<td>0.307</td>
</tr>
<tr>
<td>after 3 months</td>
<td>-0.31 ± 1.18</td>
<td>From -2.25 to +1.25</td>
<td></td>
</tr>
</tbody>
</table>

The P value shows no significant value (0.307).

Figure (8) shows the spherical Equivalent distribution of the patients who had increased ACD.
spherical Equivalent in those patients who had decreased ACD after 3 months (11 eyes):

Table (13) shows the spherical Equivalent disrtribution of the patients who had decreased ACD.

<table>
<thead>
<tr>
<th>SE</th>
<th>Mean ± SD</th>
<th>Range</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>before capsulotomy</td>
<td>-1.20 ± 2.18</td>
<td>From -5.37 to +2.5</td>
<td>1.0</td>
</tr>
<tr>
<td>after 3 months</td>
<td>-1.26 ± 1.78</td>
<td>From -5.37 to +1.125</td>
<td></td>
</tr>
</tbody>
</table>

The P value shows no significant value (1.0).

Figure (9) shows the spherical Equivalent disrtribution of the patients who had decreased ACD.
Intraocular pressure distribution of the studied group:

Table (14) Shows the IOP distribution of the studied group.

<table>
<thead>
<tr>
<th></th>
<th>Mean ± SD</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>IOP before capsulotomy</td>
<td>15.00±4.00</td>
<td>0.086 (overall)</td>
</tr>
<tr>
<td>IOP after 1 week</td>
<td>14.00±3.00</td>
<td>0.086</td>
</tr>
<tr>
<td>IOP after 1 month</td>
<td>14.00±4.00</td>
<td>1.0</td>
</tr>
<tr>
<td>IOP after 3 months</td>
<td>14.00±4.00</td>
<td>1.0</td>
</tr>
</tbody>
</table>

The overall P value shows no statistically significant value (0.086).

Before vs. 1 week (P=0.086), Before vs. 1 month (P=1.0), Before vs. 3 months (P=1.0).

Figure (10) shows IOP distribution before capsulotomy, after 1 week, after 1 month and after 3 months.
Discussion

The Nd:YAG laser capsulotomy procedure is associated with numerous complications, such as increase in the intraocular pressure (IOP), damage to intraocular lens (IOL), disruption of the anterior vitreous face, cystoid macular oedema and increased incidence of retinal detachment. (*Aslam et al., 2003*).

To predict or detect any of these complications and to take possible precautions, it is important to evaluate both anterior and posterior segment before and after Nd:YAG laser capsulotomy.

A total of 19 eyes were included and analyzed in this study (15 female eyes and 4 male eyes), the mean age of the patients was 60 ± 9 years (range 48-78 years). The mean time from cataract surgery to the Nd:YAG laser posterior capsulotomy treatment of PCO was 4 ± 4 years (range 1-17 years).

In our study, the average axial length mean of the studied group is 22.61 ± 2.10 mm (range 17.9-26.79 mm).

Current cataract surgeries require precise IOL positions to give the best refractive results, especially in premium IOLs. Thus, movement of the IOL after PCO treatment can cause refractive change and visual quality decline (*Oztas, 2015*).

We measured IOL movement by comparing ACD using A-scan ultrasound.
All The studied patients had previous phacoemulsification with implantation of foldable one piece intraocular lens and were complicated by posterior capsular opacification (PCO).

In the current study, both backward and forward movement of the IOL was detected in 8 eyes (42.10%) and 11 eyes (57.90%) respectively. We measured the ACD in the non mydriatic state.

The P value in those 8 eyes (42.10%) which had increased ACD after 3 months has significant value (0.012) and in those 11 eyes (57.90%) which had decreased ACD, the P value was (0.003) which is also significant.

Possible mechanism of myopic shift and forward movement of the IOLs may be related to positive vitreous pressure, disruption of capsule integrity and haptic design (Akmaş et al., 2018) while backward movement of the IOLs may be caused by the shock waves associated with the Nd:YAG laser that may cause mechanical effects on zonules, leading to IOL position shift by vitreous cavitation (Eliaçık et al, 2014).

These results were in agreement with (Khambhiphant et al, 2015) that included Forty-seven pseudophakic eyes with posterior capsule opacification who underwent Nd:YAG laser posterior capsulotomy. Patients’ ACD were measured before the treatment, as well as after the treatment using IOLMaster. Both backward IOL movement number n = 29 eyes (61.70%) and forward IOL movement n = 18 eyes (38.30%) were found with no statistically significant differences in ACD before and after laser treatment at 1 week and 3 months.
Another study was recorded by Oztas, 2015 and his coauthors where pentacam was used to measure the anterior chamber depth. The study included thirty eyes with three-piece intraocular lens (Sensar, AMO, USA) implantation. Mean anterior chamber depth (ACD) was 4.26 ± 0.63 mm before the procedure, 3.73 ± 0.56 mm at one week and 3.75 ± 0.56 mm at one month. The decrease in anterior chamber depth was significant (p < 0.001), so this study revealed an average of 0.5 mm decrease one week after the procedure and remained stable up to one month. This decrement in anterior chamber depth might be a clue for possible associated complications, such as unwelcome refractive errors, changes at intraocular lens position, post-procedure intraocular pressure increases and acute glaucoma.

(Akmaz et al., 2018) studied 2 groups of patients. Group-1 consisted of 35 eyes with 1-piece IOL and Group-2 consisted of 30 eyes with 3-piece IOL. ACD was measured with the Sirius rotating camera. Both IOL groups had statistically significant decrease in ACD, from baseline to the 1st week and 1st month (P=0.04 and 0.03 respectively). Possible mechanism of this forward movement of the IOLs may be related to positive vitreous pressure, disruption of capsule integrity and haptic design. Both IOL groups had statistically significant myopic shift in spherical error compared with before capsulotomy baseline values (P= 0.03 and P=0.01 respectively). The cylindrical error changes were not significant in both groups. There was minimal myopic spherical equivalent changes in 1-piece IOL group but in 3-piece IOL group there was significant myopic shift (P=0.001).
(Monteiro et al, 2018) also studied 2 groups of patients which were classified according to the IOL design: group 1 of 55 eyes (plate-haptic acrylic hydrophilic) and group 2 of 55 eyes (c-loop acrylic hydrophobic single-piece). ACD was obtained through optical coherence biometry before and 1 month after YAG laser capsulotomy. In group 1 a significant anterior movement of the IOL was detected (P = 0.02) while in group 2 a significant backward movement of the implant was observed (P = 0.025). This means that a haptic plate IOL has the tendency to move anteriorly after YAG capsulotomy, while a C-loop lens move in the opposite direction. This may be explained by the higher tension exerted by the haptics of the IOL on the capsular bag for a plate-haptic IOL, since there are 4 points of contact between the IOL and the capsular bag while in the c-loop IOL design, there are 2 points of contact between the IOL and the capsular bag. However, no significant refractive change was observed in SE, sphere, or cylinder for any group (P = 0.05).

(Ozkurt et al, 2009) revealed that there were no statistically significant differences between the anterior chamber depth before laser capsulotomy and the post-laser using the PacScan 300 AP biometer. This study included 26 eyes with Mean patient age 53.73 ± 13.53 years posterior capsular opacification after uncomplicated phacoemulsification surgery and intraocular lens implantation. The anterior chamber depth measurements were obtained in all examinations after Nd:YAG capsulotomy in all patients. Before Nd:YAG capsulotomy mean anterior chamber depth was 4.03 ± 0.58 mm and in the first day after capsulotomy the mean value was 4.02 ± 0.46 mm. There were no statistically significant differences between the anterior chamber depth before laser capsulotomy and on the first day, first month and third month after laser (P value = 0.500, 0.091, 0.061 respectively). These results are in contrast
to our results in which we found statistically significant changes in ACD after 3 months.

A study of Hu, 2000 and his coauthors showed that there were no statistically significant differences in ACD after Nd:YAG capsulotomy ($P = .201$). In this prospective study, Fifty-three eyes with posterior capsule opacification were included (22 eyes with extracapsular extraction and 31 eyes with phacoemulsification) and in-the-bag implantation of a loop-haptic intraocular lens (IOL) from 1 month to 18 years previously (mean 39 months). An Nd:YAG laser was used to perform posterior capsulotomy. Patients’ ACD were measured before the capsulotomy and 30 minutes, 1 week, and 1 and 3 months after. Anterior chamber depth was measured with an EAS-1000 (Nidek).

An early study done by Oliver Findl, 1999 and his colleagues showed increased anterior chamber depth in all patients after capsulotomy. Anterior chamber depth (ACD) was measured by dual beam partial coherence interferometry (PCI) in 32 pseudophakic eyes with posterior capsule opacification before and immediately after capsulotomy. Patients were divided into 3 groups with the following IOL styles: 1-piece poly (methyl methacrylate) (PMMA), 3-piece foldable, and plate haptic. The capsulotomy induced a backward IOL movement in all 32 eyes (mean 25 mm; range 9 to 55 mm). The plate-haptic IOLs showed a more pronounced backward movement than either 1-piece or 3-piece IOLs ($P < 0.05$). There was no significant difference in backward movement between 1-piece and 3-piece IOLs ($P = 0.73$).
As regard the refractive change caused by Nd:YAG laser posterior capsulotomy. It is important to know whether refractive changes occur after laser treatment to best determine the appropriate time periods for new corrective lens prescriptions for patients. As for the spherical equivalent, no statistically significant changes were found. (The overall P value after 3 months was 0.792).

As regard refraction, in our study we found no statistically significant changes in spherical equivalent in both groups with either increased or decreased ACD after 3 months (P-value was 0.307 and 1.00 respectively).

These results were in agreement with (Ozkurt et al, 2009) that showed that there were no significant differences between the mean spherical equivalent refraction before laser capsulotomy and post-laser on the first day, first month and the third month. However, in the study of Oztas, 2014 and his colleagues showed that there was a significant decrease in cylindrical error (p = 0.001) and a myopic shift in spherical error (p = 0.01) after the procedure; however, the difference in mean spherical equivalent was not significant (P = 0.72).

Another study of (Kambhiphant et al, 2015) found that at 1 week after laser, there were cylindrical changes that decreased after 3 months’ time. It is therefore suggested that corrective lenses can be prescribed after 3 months, once the cylindrical change has decreased. However, the shift in refraction (both SE and cylinder) was small enough that it may not be clinically relevant.
In a study done by *Chua*, 2001 and his coauthors showed that there was statistically insignificant change in spherical equivalent before and after capsulotomy by Four weeks. In this study Forty-two eyes were included. The mean spherical equivalent before capsulotomy was $-0.61 \pm 0.90$ and after capsulotomy was $-0.57 \pm 0.84$. The change in the spherical equivalent was statistically insignificant ($p = 0.14$).

Another measured outcome in our study was the intraocular pressure (IOP). All patients received a standard medical regimen after laser (0.1% brimonidine eye drop, one drop immediately after laser; and fluorometholone eye drop four times a day for 1 week). We measured IOP before, after one week, after one month and after 3 months. We found that there was no significant change in the intraocular pressure. The overall P value was (0.086), (P value = 0.086, 1.0, 1.0 at one week, one month and three months respectively). This was in coincidence with the study done by *(Ozkurt*, 2009) and his coauthors where there were no statistically significant differences between the IOP measurements before laser capsulotomy and the post-laser at the first hour ($p = 0.395$), first day ($p = 0.986$), first month ($p = 0.717$) and the third month ($p = 1.00$) and also in agreement with the study of *Oztas*, 2015 and his colleagues that revealed that there were no significant changes in the mean IOP levels at one week and one month ($p = 0.47$). The rise in IOP were within the limits of 1-3 mmHg.

Also in the study of *(Hu*, 2000) showed that IOP did not elevate significantly ($P = 0.465$), even 30 minutes after laser capsulotomy, nor was it increased according to type of cataract surgery, history of glaucoma or high myopia, or higher IOP just before the laser treatment.
Thirty minutes after the Nd:YAG capsulotomy, the highest IOP rise was 4 mm Hg in one eye only (the studied group included Fifty-three eyes.

In a study done by Ari, 2012 and his coauthors, Thirty eyes of 30 patients with posterior capsule opacification were enrolled in the study. Patients were classified according to total energy used during Nd:YAG laser capsulotomy ($\leq 80$ mJ = group I, $> 80$ mJ = group II). In group I, IOP increased 1 week postoperatively ($P = .007$) and declined to preoperative levels at 1 month. In group II, IOP increased 1 week postoperatively ($P = .001$) and did not return to preoperative levels during 3 months of follow-up ($P = .04$).

In our study the non significant P value may be due to the medications given that guard against elevation of the IOP.
Summary and Conclusion

Neodymium-doped yttrium aluminum garnet (Nd:YAG) laser capsulotomy, which was first described in 1980, is an effective technique and so-called gold standard to treat visually significant posterior capsular opacification (PCO) in pseudophakic eyes (Oztas, 2014).

Posterior capsular opacification is the most common long term complication of cataract surgery.

Nd;YAG capsulotomy can have some changes in anterior chamber depth and refraction.

Our study included 19 eyes (4 eyes of male patients and 15 eyes of female patients) who underwent cataract surgery and IOL implantation and were complicated by posterior capsular opacification. All patients received Nd;YAG laser by Zeiss VisuLAS YAG III device with a minimal duration of one year post cataract surgery.

In each visit ACD, Spherical equivalent and IOP before the procedure, then after one week, one month and 3 months were measured.

There was increase in ACD in 8 eyes (42.10%) while 11 eyes (57.90%) showed decrease in ACD. The change in ACD shows significant changes (P = 0.012, 0.003 respectively).

However, there were no statistically significant changes regarding spherical equivalent in either groups with increased or decreased ACD (P = 0.307, 1.0).

In addition, the intraocular pressure showed no statistically significant change along the follow up periods.
We believe that we have some limitations in our study because of the small number of the studied group and the short duration of the follow up periods, so we recommend to follow up larger number of patients with different types of IOLs and for longer duration.


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الملخص العربي

تعتبر عملية إزالة المياه البيضاء من أكثر العمليات الشائعة في مجال العيون والتي تشمل إزالة عتامة المياه البيضاء وزرع عدسة اصطناعية.

كما تعتبر عتامة السطح الخلفي لحفظة العدسة من أشهر المضاعفات التي تحدث في هؤلاء المرضى حيث أن نسبة حدوثها في السنة الأولى هي 11.8% و بعد السنة الثالثة 20.8%.

وبعد خمس سنوات ترتفع النسبة لتصل 42.8%.

ويرجع سبب حدوث هذه العتامة إلى وجود بعض البقايا من الألياف والخلايا التي لم يتم ازالتها جيداً من العدسة الأصلية للعين أثناء أجراء العملية.

وفي الوقت الحالي يمكن علاج هذه العتامة عن طريق استخدام البلاك لزر الذي يقوم بتنقية محور الأضبان.

وعلى الرغم من سهولة هذا الإجراء إلى أنه تجدر الإشارة إلى بعض المضاعفات التي قد تحدث من ضمنها اصابة العدسة الاصطناعية وتورم القرنية بالإضافة إلى زحزحة عدسة العين الاصطناعية عن مكانها والتي قد تؤثر على درجة أضرار العين.

كما أثبتت بعض الدراسات إمكانية تأثير ذلك على عمق الخزانة الأمامية للعين وذلك نتيجة التغيير في مكان عدسة العين المزروعة.

كما ساهمت الأجهزة الحديثة مثل جهاز الموجات فوق الصوتية وجهاز تصوير العين بالأشعة المقطعية على دراسة عمق الخزانة الأمامية للعين بدقة.

هذه الدراسة اشتملت على 19 عينا (15 عينا من المرضى الذكور و 4 عيون من المرضى الإناث).

في هذه الدراسة قمنا بقياس عمق الخزانة الأمامية للعين بواسطة جهاز الموجات فوق الصوتية قبلاً باستخدام ليزر وبعد استخدامه بساعة وشهر وثلاثة أشهر. كما قمنا بقياس ضغط العين ومقياس النظر بالكمبيوتر في المتابعة الدورية وتسجيلها ومقارنتها بعد انتهاء المتابعة الأخيرة.
المستخلص العربي

اتضح من هذه الدراسة ان بعض الحالات زاد بها عمق الخزانة الأمامية للعين (٨ مريضœ) بنسبة 48.10% والبعض الآخر من الحالات قل بها عمق الخزانة الأمامية للعين (١١ مريضœ) بنسبة 57.90% لكن على الرغم من ذلك كانت نسبة الزيادة والنقص غير مؤثرة احصائيًا ولم تؤثر على مقياس النظر في هؤلاء المرضى. اًيضا كان الاختلاف في ضغط العين غير مؤثر احصائيًا.

من هذه الدراسة يمكننا الاستنتاج ان الالح ليزر لم يؤدي الى اختلاف عمق خزانة العين او مقياس النظر او ضغط العين بصورة مؤثرة. 
تأثير علاج عتامة السطح الخلفي لحفظة العدسة باستعمال اليار ليزر على عمق الخزانة الأمامية للعين في العيون ذات العدسات الاصطناعية

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