Comparison of visual improvement based on the Potential Visual Test “Retinometry” in patients with Posterior Capsular Opacity Fibrotic and Regenerative types before and after Nd YAG Laser Capsulotomy

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ABSTRACT

Background: Posterior Capsular Opacity (PCO) can disrupt a patient’s vision and is a prevalent challenge medical professionals face in restoring visual clarity after cataract surgery. Various evaluation methods can be employed to measure visual improvement and the efficacy of Nd: YAG Laser Capsulotomy. One such method is Retinometry, which harnesses interference patterns of light on the retina as light passes through the pupil to provide patients with relevant information regarding the potential outcomes of Nd: YAG Laser Capsulotomy. This study aims to review the efficacy of the potential vision test “Retinometry” in patients with posterior capsular opacity before and after Nd: YAG Laser Capsulotomy.

Methods: Literature searching was conducted using six online databases (PubMed, Scopus, Science Direct, Clinical Key, and Google Scholar). Search terms included a combination of main keywords: “Retinometer”, “Posterior Capsulotomy”, “Nd: YAG laser”, and “Visual Acuity”.

Results: A total of 5 articles were included in this review. It’s found that the retinometer visual potential test has a function in evaluating the effects that occur and visual function after Nd: YAG laser capsulotomy. Due to the increasing incidence of cataract surgery, the rise of IOL placement will increase the risk of PCO formation and the need for Nd: YAG capsulotomy.

Conclusion: Posterior Capsular Opacity (PCO) management remains a significant concern in patients post-cataract surgery, given its potential to disrupt visual acuity. Neodymium-doped Yttrium Aluminum Garnet (Nd: YAG) laser capsulotomy is a practical approach for addressing PCO-related visual impairment. Still, its impact on visual improvement may be modest, especially regarding refractive measurements. The type of lens used does not significantly influence the procedure outcomes. As the incidence of cataract surgery continues to rise, the prevalence of PCO and the need for Nd: YAG capsulotomy are likely to increase.

Keywords: cataract surgery, laser posterior capsulotomy, ocular, posterior capsular, visual acuity.


INTRODUCTION

The most common complication in patients 2-3 years after cataract surgery is Posterior Capsular Opacification (PCO). The incidence of PCO occurs at a rate of 11.8% in the first year, 20.7% in the third year, and 28.4% in the fifth year after the surgery. Effective management of PCO is achieved by using Nd: YAG laser (Neodymium-doped Yttrium Aluminum Garnet). The laser creates a hole in the posterior capsule with the aim of restoring visual clarity.1

Retinometry examination (interference-fringes methods) is conducted by directing light through two small pupil areas traversed by two objects. Then, they overlap, creating a grating of dark and light on the retina. The retinometry examination requires good cooperation from the patient. The patient is expected to adjust their head position slightly to allow the retinometer light to enter the refractive media haze gap. The examination is best performed with a dilated pupil.2

This research assessed the improvement in visual acuity in patients with fibrosis and regenerative type of PCO using Retinometry after undergoing Nd: YAG laser capsulotomy. Therefore, the author believes it is still necessary to conduct research on the Efficacy of the Potential Vision Test “Retinometry” in patients with Posterior Capsular Opacity before and after Nd: YAG Laser Capsulotomy.3

METHODS

This literature review was cited from reliable sources such as (PubMed, Scopus, Science Direct, Clinical Key, and Google Scholar). It utilized a database from 2014 until 2023. The keywords Retinometer”, “Posterior Capsulotomy”, “Nd: YAG laser”, and “Visual Acuity” were used to collect...
that had relevant topics. The reports were considered eligible if they met the following inclusion criteria:
1. Subjects had posterior capsular opacity (PCO).
3. The primary outcome was visual acuity measured using retinometry.

The search was limited to articles with the human sample, subject area of medicine and neuroscience, published in English, and available full-text reviews and articles.

RESULT

The database searches yielded 5 published studies. After removing duplicate articles, we looked through the titles and abstracts of the remaining research to find pertinent papers.

Posterior Capsule Opacification (PCO)

Phacoemulsification and small incision cataract surgery are procedures used for cataract management. Posterior Capsule Opacification (PCO), also known as secondary cataract, is one of the most common complications following cataract surgery. Over the past decade, various preventive measures have been employed, including actions during surgery (surgical techniques, intraocular lens materials, and intraocular lens design), pharmacological prevention, and interfering with the biological processes involved in preventing PCO.1

In a normal crystalline lens, Lens Epithelial Cells (LEC) are limited to the anterior surface and equatorial lens curvature. It is organized as a single layer of cuboidal epithelial cells. It has two biological zones: a flat cuboidal epithelial cell layer (known as ‘A’ cells) with minimal mitotic activity in the anterior capsule zone and anterior epithelial cells in the equator forming the equatorial lens bow (‘E cells’). Unlike ‘A’ cell layers, these ‘E’ cells have mitotic activity and undergo multiplication.1 New lens fibers are continually produced in this zone throughout life.4 Research by Apple et al.5 found that LEC proliferation plays a significant role in the pathogenesis of anterior capsule opacification (ACO), PCO, and intralenticular opacification (ILO). Marcantonio and Vrensen6 studied PCO cell biology and demonstrated that PCO is generated from the growth and transdifferentiation of LEC left behind in the anterior capsule during cataract surgery. These cells proliferate to form a single layer on the capsule surface. Some cells differentiate or transition into other cell types, and this process significantly contributes to the formation of PCO.1

Two types of epithelial cells cause two types of PCO: fibrotic and pearl or proliferative. The first type of PCO involves anterior epithelial cells located in the central zone of the anterior capsule, consisting of relatively non-mitotic LEC. The second type of PCO occurs when pluripotent cells gather around the equatorial capsule. When activated by interleukin, these cells migrate to the posterior.2

Regenerative / Elschnig pearls:3 Regenerative PCO is considered the production of lens fibers from residual lens epithelial cells, although this is still debated. It occurs more frequently and is a major reason for decreased visual function after IOL implantation. Regenerative PCO appears similar to Wedl cells, which play a role in the formation of subcapsular posterior cataracts, as Wedl cells are known to originate from equatorial lens epithelial cells. The remaining equatorial cells are believed to play a role in forming Elschnig Pearls. After surgery, these cells proliferate and migrate centrally, infiltrating the space between the posterior capsule and the IOL optic. Elschnig Pearl adhesion to the capsule bag is not strong, so it can be easily cleaned with a cannula or spatula and aspirated. Elschnig pearls usually develop more slowly than the fibrotic type.7

Fibrosis:

‘A’ cells located at the edge of the rhexis potentially undergo transdifferentiation into myofibroblast-shaped, wrinkled, cloudy lines resembling grayish-white lines and plaques on the posterior capsule surface, also known as fibrosis. These cells proliferate and migrate to the posterior capsule to form a layer that releases extracellular matrix components such as collagen type I and III and materials like the basement membrane. Contraction of these cells will create fine folds and wrinkles on the posterior capsule. At this stage, the opacification in the capsule is mild and does not cause visual disturbance unless the cells migrate to the visual axis.7

Development Stages of PCO

Proliferation: Proliferation begins 3 to 4 days after cataract surgery. Removing lens fibers during cataract surgery can trigger the proliferation of Lens Epithelial Cells (LEC). The residual lens cortex can also induce PCO proliferation. Melanocytes from the iris and cells released into the bloodstream due to damage to the blood-aqueous barrier play a role in initiating PCO proliferation. Intraocular lenses (IOL), being foreign objects, can trigger an inflammatory process. Autocrine and paracrine actions play a role in the proliferation of LEC in the posterior capsule. Autocrine signaling prompts residual LEC to release various cytokines that control the development of PCO.8

Migration: LEC migrates toward the posterior capsule due to the presence of molecules such as Integrins Subunit, Cell Adhesion Molecule (CAM), and Hylauronan CD 44 receptor. The Gly-Arg-Gly-Asp-Ser-Pro (GRGDSP) RGD peptide inhibits cell attachment and migration on laminin and fibronectin Arg-Gly-Asp. Matrix Metalloproteinases (MMPs), a group of proteolytic enzymes, play a significant role in cell migration and wound healing.8

Differentiation: LEC can differentiate normally and abnormally. Normal differentiation involves LEC directing the formation of pearl-like structures in the posterior capsule known as bladder cells. Bladder cells appear among LEC during the formation of fibrotic cells in the lens and can regress over time. These cells have granular cytoplasm homogeneous with pyknotic nuclei and do not produce αSMA, a protein used as a marker for myofibroblast formation.8

Symptoms include continuously worsening blurred vision, glare, and sometimes monocular diplopia. Visual acuity varies, although dysfunction may

be more noticeable in contrast sensitivity testing. Signs usually include more than one type of opacification, and there are several forms of PCO.9

PCO vacuolated (pearl type) consists of proliferating LEC, similar to balloon cells (Wedl) seen in subcapsular posterior cataracts. This type is often called 'Pearl-Elschnig' and has a characteristic appearance of swollen, round or grape-like clusters of cells seen after trauma or anterior capsule rupture surgery. Fibrotic PCO is believed to be caused by the fibroblastic metaplasia of epithelial cells. A soemmering ring is the proliferation of residual cells in an annular or donut shape, a whitish appearance that typically forms near the periphery of the capsule bag after a longer duration of cataract surgery. It can form on the edge of capsulorhexis or capsulotomy.10

Management involves creating an opening in the posterior capsule using Nd: YAG laser (called posterior capsulotomy). Indications include visual symptoms, such as reduced vision and glare. Capsulotomy is usually performed to improve inadequate fundus view that interferes with assessing and managing the posterior segment abnormalities. Complications may include pitting of the IOL, which is usually not visually disruptive.11,12

Nd: YAG Laser Posterior Capsulotomy

Management for PCO involves YAG capsulotomy using Neodymium: Yttrium-Aluminum-Garnet (Nd: YAG) laser directed at the implanted lens and focused on the hazy posterior capsule. This laser opens the posterior capsule to allow unhindered light transmission to the retina, eliminating opacities obstructing vision. This procedure is also known as posterior capsulotomy. This solid-state laser emits a low-divergence wavelength at 1064 nm (1% Nd doping). Light refraction results in ionization and plasma formation in ocular tissues.13

Influence of Nd: YAG laser on tissues:13

• Photocoagulation: Tissues exposed to the laser will increase to 37°C–50°C. This occurs because converting light into heat energy causes protein denaturation and tissue coagulation.

• Photodisruption: Tissues exposed to the laser will increase from 37°C–15000°C. This occurs due to hydrodynamic and acoustic shockwaves, mechanically tearing tissues at the microscopic level.

• Photoablative decomposition: There is no temperature increase due to short-wavelength ultraviolet light.

There are two types of Nd: YAG laser beams, Q-switched and Mode-Locked. Q-switched compresses energy within one nanosecond, producing higher energy, while Mode-Locked generates energy in picoseconds and has lower energy. For Q-switched lasers, the power used is 1–2.5 mJ/pulse, while for Mode-Locked lasers, the power used is 3–5 mJ/pulse.13

The most commonly used capsulotomy technique is Seaman’s, which includes:

• Vertical opening, starting from 12 o’clock to 6 o’clock.

• Horizontal opening, starting from 9 o’clock to 6 o’clock.

• Concentric spreading, starting from the periphery towards the center.

• Fragmentation, widening the edge of the fibrotic membrane.

High laser energy causes ionization, leading to the interaction between photons and atoms, creating a radiation wave that damages tissues. Laser light and tissues are influenced by the laser’s wavelength, exposure time, and irradiation (energy per unit area, Watt/cm²). High photon energy can induce photoreactions. Light absorption by tissues generates heat and causes thermal denaturation. Plasma mediates the interaction between the laser and the posterior capsule, resulting in plasma heating and vaporization, producing shockwaves and bubbles that damage the posterior capsule.13

The optimal capsulotomy diameter should be the same as or exceed the pupil diameter under scotopic conditions (3.9 ± 0.5 mm) and remain within the IOL boundaries. Various shapes and sizes of Nd: YAG laser capsulotomy patterns can be used. Circular and cruciate patterns are most frequently applied, with openings ranging from 3-6 mm. This provides certain advantages and disadvantages. In the cruciate pattern, the first laser shot is directed superiorly near 12 o’clock and moves downward to 6 o’clock, and then laser shots are placed at the edges of the capsular opening, moving laterally towards 3 and 9 o’clock. In the circular pattern, laser shots start from the 6 o’clock position and move circularly, with cruciate pattern Nd: YAG laser posterior capsulotomy is performed safely, and visual acuity prognosis is better with the circular pattern than with the cruciate pattern.13

Complications

This method has a 95% success rate, is quicker, relatively easy, convenient, and does not require hospitalization. However, there are still possible post-procedure complications. Common complications following Nd: YAG laser capsulotomy include:14

• Increased IOP: Increased intraocular pressure is the most common complication following Nd: YAG laser capsulotomy.

• IOL Position and Refraction Changes: There are reports of IOL dislocation after Nd: YAG laser capsulotomy, where larger capsulotomy openings may induce more significant backward movement.

• IOL Damage/Pitting: There have been observations of IOL pitting, but in most cases, mild or small pitting does not affect vision.

• Iritis/Uveitis: Some patients may experience anterior uveitis, manifesting as cell and flare in the anterior chamber during slit lamp examination.

• Rupture of the Anterior Hyaloid Membrane: Nd: YAG laser can affect the anterior chamber’s depth, leading to the rupture of the anterior hyaloid, causing the vitreous and IOL displacement movement.

• Cystoid Macular Edema (CME): CME can occur due to the movement of vitreous and vitreous damage, releasing inflammatory mediators.

• Retinal Tear and Detachment: Patients with larger capsulotomies may experience hyperopic shifts, potentially leading to retinal tears and detachment.

• Other Complications: Other reported complications include glaucoma due to pupil block, misdirection aqueous syndrome, macular hole, and endophthalmitis.

Retinometry

Retinometry examination (interference-fringes methods) passes light through 2 small areas in the pupil traversed by 2 objects, overlapping them, creating
a grating of dark and light shadows on the retina. This examination provides a measure called grating visual acuity with values ranging from 0.1 to 1.0. The first retinometer was a slit lamp attachment that projected a mini-Snellen chart into the eye. This early retinometer was found to be ineffective in estimating postoperative visual acuity. This quantitative instrument has since evolved to determine the potential visual acuity of eyes with refractive media opacities. 5

Retinometry is one of the types of interferometry or clinical interferometer methods, along with pinhole aperture and potential acuity meter, which can assess visual acuity directly at the macula. Therefore, it falls under non-wall projection charts for visual acuity assessment. Retinometry uses the principle of interference fringes to assess patients' visual acuity through a cloudy lens. The results of retinometry are highly dependent on retinal function rather than on refractive media, as the light pattern on the retina is not formed through imaging. Interference occurs when two light sources meet and appear as waves moving as long as the macula functions. This effect occurs even in the presence of cataracts or refractive abnormalities. 6

Heine Lambda 100 Retinometer
The Heine Lambda 100 Retinometer (HEINE Optotechnik GmbH & Co, retinometer, Dornierstr, Glinching, Germany) is a portable handheld device consisting of a rechargeable handle and a slit lamp. It uses a red xenon light that penetrates cataract opacities and directly stimulates the macula to provide an estimate of BCVA. Red and black line images corresponding to the Snellen chart, which can change position up to 45 degrees, are projected. The thinner the lines visible to the patient, the better the postoperative visual acuity that can be achieved. A study in Israel evaluated this retinometer in 374 eyes undergoing cataract surgery. The retinometer showed accurate estimates (postoperative BCVA in 2 lines of the retinometer's estimate) in 60% of patients, with 27% underestimating (postoperative BCVA greater than 2 lines below the retinometer's estimate) and 12% overestimating (postoperative BCVA greater than 2 lines above the retinometer's estimate). These findings indicate that the retinometer is accurate for most cases and tends to provide values below predictions rather than above. In the same study, the level of cataract (based on color and opacity) did not affect the retinometer's predictive ability. 7

DISCUSSION
Effect of Nd:YAG laser capsulotomy on visual outcomes and retinometry in PCO patients. The PCO is the most common late complication of conventional ECCE or phacoemulsification. The YAG laser capsulotomy PCO can improve both distant and near vision, which can be augmented by optical correction one month after surgery. The procedure can be performed in the outpatient, being simple. But the procedure is not without hazards. 8

The treatment of PCO patients using Nd: Yag laser has become the standard procedure for managing posterior lens capsule opacification. The Nd: YAG laser uses photo disruption to produce acoustic shock waves, creating openings in the posterior capsule. Indications for this laser procedure include decreased BCVA due to posterior capsule opacification posterior capsule opacification causing difficulty in evaluating the patient's posterior segment, monocular diplopia, glare, and anterior capsule phimosis. Contraindications for this procedure include impaired visualization of the posterior capsule, uncooperative patients, active eye inflammation, and uncontrolled glaucoma.

It found that the accuracy of the Lambda retinometer's estimates (within 2 Snellen lines) predicted postoperative BCVA outcomes in 60% of cases out of a total of 374 patients. The predictive accuracy was significantly better for moderate cataracts compared to advanced cataracts. 9

Eyes with postoperative BCVA more than 2 lines above the Lambda measurements were categorized as underestimated, while eyes with postoperative BCVA more than 2 lines below Lambda were categorized as overestimated. All others were categorized as accurate predictions (BCVA within 2 lines of Lambda measurements). 10

A study showed a tendency for increased IOP 2-3 hours after laser capsulotomy. 21 The higher energy levels greater than 1.5 mJ. The higher the laser energy, the higher the laser pulse energy, and the higher the incidence of increased IOP. Increased IOP can pose a threat to vision. 21 In a study by Utami and Dyah, a retinometry scale of 0.8 was most frequently found in patients with a BCVA of 1.0 (56.8%). One eye with a retinometry scale of 0.32 could achieve a BCVA of 1.0, and this patient fell into the category of high myopia (S: 12.5D/C: 0.75 D x 17°). 21-24 The best corrected visual acuity of 6/9 to 6/6 was achieved in 328 patients (65.6%) and 6/12 to 6/18 in 163 patients (32.6%); 98% of the patients achieved improvement of visual acuity of more than 2 lines. 25 After Nd: YAG Laser results show that Nd: YAG capsulotomies appear to cause a statistically significant, but arguably clinically negligible, decrease in cylinder magnitude. The type of lens does not alter the change in postoperative refractive measurements. Due to the increasing incidence of cataract surgery, the rise of IOL placement will increase the risk of PCO formation and the need for Nd: YAG capsulotomy. 11

References to retinometry visual results associated with posterior capsule opacity are still limited; however, Retinometry, with its capacity to generate interference patterns of light on the retina, has shown promise as an effective means of assessing visual improvements. The examination, though reliant on patient cooperation and dilated pupils, has the potential to provide valuable insights into the comparative efficacy of Nd YAG Laser Capsulotomy in fibrotic and regenerative PCO cases.

CONCLUSION
In the pursuit of optimizing visual outcomes for patients with Posterior Capsular Opacity (PCO), our study has delved into assessing and comparing visual improvements in individuals afflicted with fibrotic and regenerative types of PCO. The increasing incidence of PCO over time underscores the importance of effective management. The Neodymium-doped Yttrium Aluminum Garnet (Nd: YAG) laser capsulotomy is a valuable intervention for restoring visual clarity in PCO patients. However, our focus on evaluating the efficacy of the Potential Vision Test, Retinometry,
in assessing visual acuity before and after this procedure has further illuminated the significance of employing a diagnostic tool tailored to PCO characteristics.

This article review hopes to contribute to a deeper understanding of the complex dynamics surrounding visual outcomes in PCO patients. Additionally, we emphasize the need for continued research to enhance the assessment and management of Posterior Capsular Opacity, ultimately advancing the quality of care and outcomes for individuals affected by this condition.

AUTHOR CONTRIBUTION

G.A.M: Editing, final review and approved the final manuscript.
M.A.I: Design, editing and writing of the manuscript, supervision of the paper, and approved the final manuscript.
HZ: Design, editing and writing of the manuscript, supervision of the paper, and approved the final manuscript.

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The authors declare no conflict of interest.

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REFERENCES