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Effect of Nd:YAG Laser Posterior Capsulotomy on Corneal Endothelial Cell Count in Relation to the Power of Laser Used

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Abstract: ***Posterior capsule opacification (PCO) is the most common visually disabling consequence of modern cataract surgery and has important medical, social and economic implications. Purpose: To compare corneal endothelial cell count before and after Nd:YAG laser capsulotomy, in patients with posterior capsule opacification among 2 groups. Method: Prospective, interventional study, including 100 eyes of 100 clinically diagnosed PCO patients, who were willing to undergo Nd:YAG laser capsulotomy. The patients were divided into 2 groups: Group-A (20 patients) Single pulse energy of 1.6mJ with total energy less than 10mJ was given. Group-B (20 patients) Single pulse energy of 2.2mJ with total energy less than 20mJ was given. The changes were observed at 2 hours, 2 days, 2 weeks, 2 months and 6 months. Data was analysed using unpaired t-test. Result: The difference between pre and post laser corneal endothelial cell count was found to be statistically significant. Finally in the 6th month post laser the cell loss was found to be 175.68 ± 72.42 cells/mm^2 (10.43%) and 214.88 ± 97.68 cells/mm^2 (12.97%) in group A and B respectively. Conclusion: a lower single pulse energy with lesser total energy (<10mJ) treats PCO with lesser adverse effects.***

Keywords: Nd: YAG Laser, Posterior capsulotomy, Endothelial cell count, Posterior capsule opacification

1. Introduction

Modern cataract surgery can provide good visual outcomes for most patients, owing to the developments in surgical technique, instrumentation and intraocular lens (IOL) technology. Unfortunately, despite advances in lens design and material, we cannot always prevent the main late complication associated with cataract surgery: posterior capsule opacification (PCO).
Posterior capsule opacification is a condition which develops months or years after successful cataract surgery. The time from surgery to visually significant opacification varies from months to years.

Sundelin and Sjostrand, have defined visually significant PCO as a decrease in post-operative best corrected visual acuity by two Snellen lines[1].

Posterior capsule opacification (PCO) (Figure 1) is the most common visually disabling consequence of modern cataract surgery and has important medical, social and economic implications[2].

The reported incidence of PCO varies widely. Analysis of multiple reports has found the visually significant PCO rate overall to be approximately 11.8% at 1 year, 20.7% at 3 years and 28.4% at 5 years after cataract surgery[3]. It can lead to clinically significant reduction in visual acuity, impaired contrast sensitivity, glare disability and monocular diplopia.

At present, the most effective treatment of PCO is Nd:YAG laser capsulotomy. It is a safe and non-invasive method of managing PCO. The procedure involves clearing of the visual axis by creating a central opening in the opacified posterior capsule by focusing a Nd:YAG laser pulse, with energy of few millijoules and duration of a few nanoseconds, just behind the posterior capsule.

Although Nd:YAG laser capsulotomy presents the advantage of being a non- invasive and effective method to treat PCO, its adverse effects reported in literature include **intraocular pressure elevation**, cystoid macular oedema, **endothelial cells reduction and damage**, retinal tears and detachment[4] and, most commonly, intraocular lens (IOL) damage, or so-called pitting[5]. **Some authors reported that side effects were more pronounced when higher single-pulse energy rather than higher total energy was used**[6].

PCO usually develops due to the epithelial cells of the lens being left behind in the capsular bag after any type of extracapsular cataract surgery [7]. Different experimental studies [8-10] have suggested that the posterior capsule (PC) itself does not opacify. PCO occurs as a result of the formation of opaque secondary membranes by proliferation, migration, epithelial-to-mesenchymal transition, collagen deposition, and lens fiber regeneration of the lens epithelial cells[11].

The lens epithelial cells proliferate in several patterns. Clinically, there are two basic morphological types of PCO, the fibrosis type and the pearl type, which have different cellular origins [7]. The fibrosis-type PCO is caused by the proliferation and migration of the lens epithelial cells, which undergo an epithelial-to-mesenchymal transition, resulting in fibrous metaplasia [12]. In contrast, the pearl-type PCO is formed by the lens epithelial cells located at the equatorial lens region. These cells generate the regeneration of crystallin-expressing lenticular fibers and the formation of Elshing pearls and a Soemmeringring [7].

There is a need to evaluate the minimum safe threshold of power of each pulse given in Nd:YAG capsulotomy and the total energy that can be delivered safely while performing Nd:YAG laser capsulotomy.

Hence, the purpose of this study is to observe the minimum safe energy that can be given while performing Nd:YAG laser capsulotomy by comparing the Nd:YAG laser capsulotomy effects on the corneal endothelium cell count based on different power used for laser capsulotomy in two different study groups, thus enabling us to get the best treatment results using lower energy and fewer shots.

2. Literature Survey

Posterior capsule opacification (PCO, secondary cataract) has existed since the beginning of extracapsular cataract surgery (ECCE) and indeed was noted by **Ridley,** in his very first IOL implantation in **1949**.[14, 15] It was particularly common and severe in the early days of IOL surgery (in the late 1970s and early 1980s) when the importance of cortical cleanup was less appreciated. Through the 1980s and early 1990s, the incidence of PCO ranged between 25-50% (**Aron Rosa et al, 1984)**[16].

Allan R. Slomovic, Richard K. Parrish II et al[17] in **1986** conducted a study to determine central corneal endothelial cell densities in 39 eyes in a masked fashion before and after Q-switched neodymium-YAG laser posterior capsulotomy. The mean preoperative and postoperative endothelial cell count was 1, 840 and 1, 798 cells per square millimeter respectively. The difference between the mean preoperative and postoperative cell density was 42 cells per square millimeter (2.3% cell loss). There was no significant correlation between central corneal endothelial cell loss and the laser energy used.

Beat Zysset, Dr. James G. Fujimoto et al[18] in **1989**, did a study to evaluate the effects of picosecond laser-induced optical breakdown on tissue using high-intensity 40psNd:YAG laser pulses at 1.06µm. A minimum damage range of less than 100µm was observed for pulse energies of 8µJ.**Comparative studies using 10 ns pulses demonstrated that picosecond pulses yielded a significant reduction in collateral tissue damage.**

Similar study was done by **Vaikoussis, E., Bisogiannis, Z. &Margaritis**[19] in **1993** in patients who had extracapsular cataract extraction, to evaluate the pathologic changes caused by high powered Nd:YAG laser pulses on the anterior segment of the eye. They studied acute corneal endothelial changes 6 hours after the capsulotomy using transmission electron microscopy. Results indicated that especially in the high setting the laser energy can cause injury and destruction of endothelial cells and alterations in the Descement membrane.

Vassilios P Kozobolis et al[20] in **1998**, conducted a study to evaluate the corneal changes after Nd:YAG laser pupillary membranectomies (group A), iridotomies (group B), and capsulotomies (group C) in a follow-up period of 6 months. A non-statistically significant decrease of cell density was recorded by the end of the first month. A significant loss of endothelial cells during the sixth month was recorded in groups A and C.

A study conducted in **2012** to estimate the mean Nd:YAG laser capsulotomy energy levels in various types of PCO by **Bhargava et al**[21] showed that fibro-membranous PCO required more summated energy despite a lower starting energy.The statistic mean values of initial energy levels were 1.80 mJ for membranous PCO, 3.17 mJ for fibrous PCO and 2.73 mJ for fibro-membranous PCO. The mean summated energy levels for membranous PCO were22.80 mJ for membranous PCO, 80.06 mJfor fibrous PCO and 80.48 mJ for fibro-membranous type.

A similar study was conducted by **GregorHawlina et al**[22] in **2013** to observe the total energy delivered while performing the Nd:YAG laser capsulotomy using a cruciate pattern with a size of 4mm and single pulse energy of 1.6 mJ. A lower single-pulse but higher total energy was used. They documented that the total amount of energy delivered to the treatment site can be decreased by using higher single-pulse energy, but this may potentially lead to a higher incidence of adverse effects.

3. Methods

The study was a prospective interventional and observational study, including 100 eyes of 100 patients in each group coming to the outpatient department of Ophthalmology at Chhatrapati Shivaji Subharti hospital, Meerut, who were willing to undergo Nd:YAG laser capsulotomy. The eyes were subjected to Nd:YAG laser and followed up till 6 months to evaluate the damage caused by laser on the corneal endothelium.

All cases underwent a detailed preoperative evaluation including vision, refraction, anterior segment and posterior segment examination. An informed consent was taken from all the patients in the study and an ethical clearance was also taken from the ethical committee of Subharti Medical College. Patients above 45 years were included in the study, while those with any significant corneal pathology, uncontrolled glaucoma and endothelial cell count less than 1200/mm^{2}were excluded.

The patients were divided equally in 2 groups of 50 each, depending upon the type of posterior capsule opacification. Since the fibrous type of posterior capsule opacification is thicker as compared to the Elschnig pearl type of posterior capsule opacification, the fibrous type comparatively requires higher Nd:YAG laser energy. Hence, we kept the patients with Elschnig pearl type of PCO in group A who received lesser total laser energy and patients with fibrous PCO in group B who received greater laser energy.

Group A- Single pulse energy of 1.6 mJ with total energy less than 10 mJ

Group B- Single pulse energy of 2.2 mJ with total energy less than 20 mJ

Ophthalmological Evaluation

Examination

1. Visual acuity and best corrected visual acuity in each case was determined using Snellen's chart.
2. Examination of anterior segment was done on the slit lamp to rule out any corneal or anterior chamber pathology.
3. Intraocular pressure was recorded using TOPCON (CT-80) Non Contact Tonometer.
4. Examination of posterior segment was done by direct ophthalmoscope and slit lamp biomicroscopy using a +90D Volk lens.
5. Endothelial cell count and cell density was documented using a non-contact specular microscope (Topcon SP-3000P)

Procedure

A) Specular microscopy examination (Figure 2) of the corneal endothelium was done to assess the central corneal endothelial cell count before and after Nd:YAG laser capsulotomy. Specular microscope model (Topcon SP-3000 P) was used to record the central corneal endothelial image. The corneal endothelial cell count was calculated using the cell center method. Standard deviation of the endothelial cell size from the mean, coefficient of variation and hexagonality of the endothelial cells was also evaluated using non-contact specular microscope (Topcon SP-3000P).

B) Preparation of the patient for Nd:YAG Capsulotomy

a) Before Treatment Session

Complete ophthalmic history was taken and examination was done. Discussion of the proposed procedure, including risks and benefits was done with all the patients. Informed consent was taken from all the patients. Pupillary dilation was done before conducting YAG capsulotomy. Application of topical anesthetic once the pupil was dilated.

b) During Laser Treatment

Patient was asked to fixate the other eye at the fixation target. Adjustment of stool, table and chin rest was done for optimal patient comfort. Application of head strap to maintain forehead position. Darkening of the room was done.

C) Posterior Capsulotomy Technique

A 4mm cruciate opening, beginning superiorly near the 12 o'clock position and progressing downward toward the 6 o'clock position was made.

Unless a wide opening was already developed, shots were then placed at the edge of the capsule opening, progressing laterally toward the 3 and 9 o'clock positions.

If any capsular flaps remained in the pupillary space, the laser was fired specifically at the flaps to cut them and cause them to retract and fall back to the periphery. The goal was to achieve flaps based in the periphery inferiorly. Free-floating fragments were avoided to prevent visual interference.

To avoid IOL marks, the laser was intentionally focused posterior to the capsule, causing optical breakdown in the anterior vitreous. The shock wave radiates forward and ruptures the capsule. Optical breakdown just at the capsule and IOL surface, with resultant IOL marking, was avoided.

While performing the Nd:YAG laser procedure in each eye, we counted the number of laser pulses, N, that induced an optical breakdown (i.e., the plasma spark was visible). The total-pulse energy, Etot, required to create the PC opening was defined as $E_{tot} = N \times E_p$. Here, E_p stands for the single-pulse energy.

4. Results

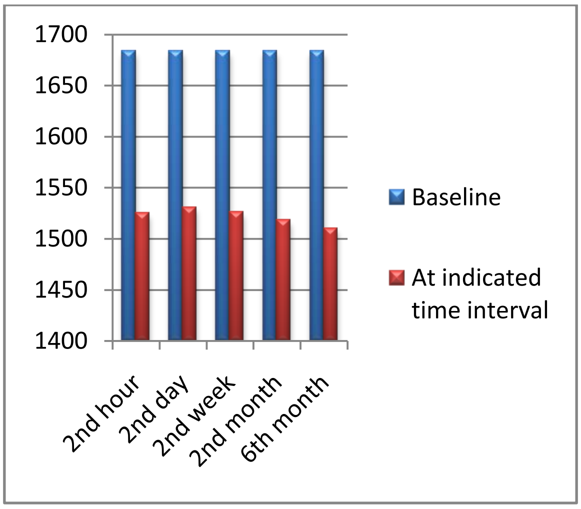
In the present study, 100 patients were included and divided into 2 groups (Group A& Group B) the majority of patients were of age group ranging from 65-75 years.

In both the groups, the majority of patients were female (72.0% and 62.0% in group A and B respectively) followed by male (28% and 38% respectively).The laterality of eye in group A was right in 58.0% followed by left in 42% while in group B the laterality was left in 52.0% followed by right in 48.0%.

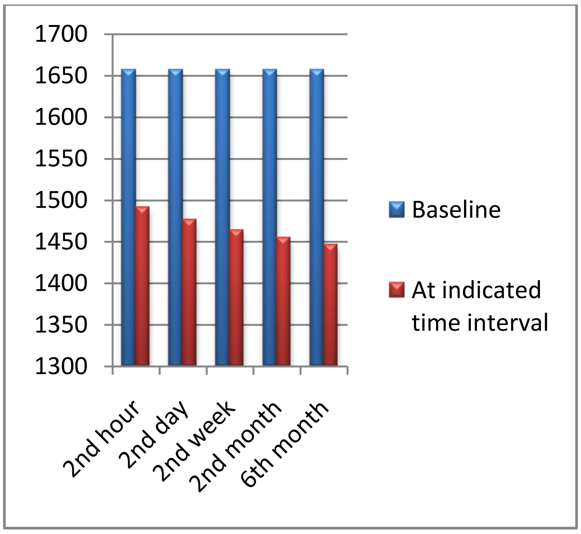
Table 1: Comparison of Baseline Clinical Data in both groups

	Group A (n=50) Mean ± SD	Group B (n=50) Mean ± SD
Total mean pulses	5.06 ± 0.87	7.56 ± 1.33
Total Mean energy (mJ)	7.98 ± 1.23	16.49 ± 2.83

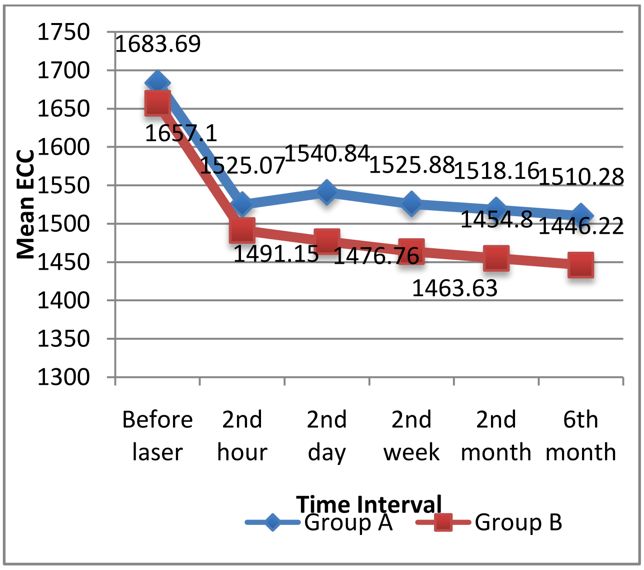
The final difference in cell loss at 6 months between group A and B was found to be statistically significant (p value- 0.0248, considering p value <0.05 as statistically significant).Comparison of Mean cell loss in ECC from the baseline (pre-YAG) value in both groups was found to be statistically significant at all follow-ups (p<0.001).Finally in the 6th month post laser the cell loss was found to be 175.68 ± 72.42 cells/mm2 (10.43%) and 214.88 ± 97.68 cells/mm2 (12.97%) in group A and B respectively.



Graph 1: Comparison of Mean Endothelial Cell Count from baseline at various intervals in Group A



Graph 2: Comparison of Mean Endothelial Cell Count from baseline at various intervals in Group B



Graph 3: Comparison of Mean Endothelial Cell Count between both the groups at various time intervals

The improvement in UCVA and BCVA at each follow up from the baseline in both Group A and B was found to be statistically significant (p<0.0001). However, the comparison of UCVA and BCVA between Group A and B was found to be statistically non-significant (p>0.05).

5. Conclusion

At present, the most effective treatment of PCO is Neodynium Yttrium Aluminium Garnet (Nd:YAG) laser posterior capsulotomy. Although Nd:YAG laser capsulotomy presents the advantage of being non-invasive and an effective method to treat PCO, it is not free of complications. The corneal endothelium can be damaged by laser radiation.

Therefore, research aimed at reducing the complications of Nd: YAG laser, chiefly being the loss in the endothelial cell count and variations in IOP is highly desirable.

Our results suggest that though Nd:YAG laser capsulotomy is a safe procedure, it may pose a long-term hazard to the corneal endothelium, especially if high laser energy is delivered to the eye. Thus, a lower single pulse energy with lesser total energy (<10mJ) treats PCO with lesser adverse effects in comparison to a higher single pulse energy with a greater total energy level which may lead to a higher incidence of adverse effects, ie, a greater loss in the endothelial cell count.Early PCO evaluation, accurate use of the laser shots and correct technique for laser posterior capsulotomy, all help the surgeon to move towards the goal of emmetropiapost secondary cataract laser treatment.

Strengths of the study

This study is a non randomized controlled interventional trial with an adequate sample size (100: Group A-50 and Group B-50) and none of our patients were drop out till the end of the study due to any reason.

6. Limitations

There were few limitations of our study i.e., it did not show the macular and retinal changes post YAG laser and it doesn't show the long term visual acuity follow up and also no long term follow ups were performed in our study.

To conclude, in a developing and overpopulated country like India, especially in a setup like ours, where patients belong mostly to the rural population, and usually do not turn up for regular follow ups, it is necessary to use laser energy as minimal as possible to treat post capsular opacification and hence, reduce the risk of complications after posterior laser capsulotomy.

Also, a good suggestion would be to carry out a similar study with a larger study group and a longer follow-up, to further prevent any complications associated with Nd:YAG laser and to further increase the scope of the study.

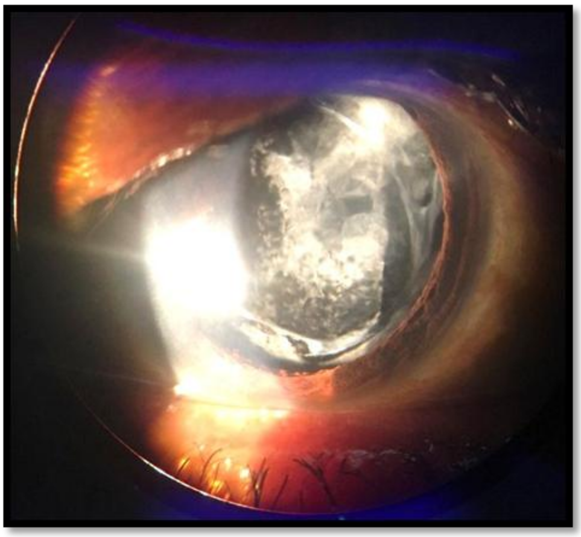


Figure 1: Posterior Capsule Opacification

Figure 2: Specular Microscopy

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