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Evaluation of Nd:YAG laser capsulotomy results in patients who underwent cataract extraction and intraocular lens implantation with the endocapsular phacoemulsification method

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This study was approved by the Ethics Committee of Harran University, 01.06.2006/4.
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Abstract

Background/Aim: Posterior capsular opacification (PCO) is a common complication that develops after cataract surgery, and it can be treated neodymium-doped yttrium aluminum garnet (Nd:YAG) laser capsulotomy. In this study, we aimed to investigate the effects of different intraocular lenses (IOLs) on the development of posterior capsule opacification (PCO), to determine the time between surgery and Nd:YAG laser capsulotomy, and to evaluate the efficacy, effectiveness, and complications of capsulotomy in patients who underwent cataract surgery with the phacoemulsification method and subsequently developed PCO.

Methods: The cohort study included one eye of each of 153 cases (63 males, 90 females) who underwent cataract surgery with the phacoemulsification method in our clinic from August 1, 2006, through August 1, 2008, and subsequently developed PCO. According to the type of IOL implanted, the cases were divided into three groups: polymethylmethacrylate IOL (Group 1), hydrophilic acrylic IOL (Group 2), and hydrophobic acrylic IOL (Group 3). The control examinations of the patients who underwent Nd:YAG laser capsulotomy were undertaken before capsulotomy and at the first week, first month, and third month after capsulotomy.

Results: Visual acuity improvement was detected in 96.7% of the 153 cases. It was determined that 9.1% of the cases had an intraocular pressure (IOP) increase of more than 5 mmHg at the third hour after capsulotomy and approached baseline values at the end of 1 week. The mean total energy used in all the cases was 37.20 (14.70) mjl. The mean total energy used in 14 patients with an IOP elevation of above 5 mmHg was 71.07 (10.59) mjl. Nd:YAG laser capsulotomy was performed at an average of 6.29 (4.91) months in Group 1, 7.81 (4.35) months in Group 2, and 17.7 (12.35) months in Group 3. After capsulotomy, clinically significant cystoid macular edema was observed in 1.9% of the cases, IOL damage in 3.9%, and vitreous hemorrhage in 0.6%.

Conclusion: In this study, the incidence of PCO development was found to be lower in the patients who underwent hydrophobic acrylic IOL implantation; therefore, this type of lens should be preferred for implantation. Although Nd:YAG laser capsulotomy is an outpatient treatment method that can be applied quickly and can increase visual acuity, it can also lead to complications. To eliminate most of these complications, it would be beneficial to minimize the energy used during the laser procedure.

Keywords: posterior capsular opacification, intraocular lens, Nd:YAG laser, capsulotomy, endocapsular phacoemulsification

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Introduction

Posterior capsular opacification (PCO) is a common long-term complication that develops after cataract surgery and causes findings such as decreased visual acuity, photophobia, and glare [1–3]. The incidence of PCO after cataract surgery has been reported to vary between 2.5% and 50% [4].

PCO occurrence may depend on patient-related factors, the surgical technique applied, or the characteristics of the intraocular lens (IOL) implanted [2–5]. Not only the material of IOL, but also its edge profile and localization, are important in the formation of PCO [4,5]. Other predisposing factors for the development of PCO include younger age, surgical complications, trauma, uveitis, and diabetes mellitus (DM) [5].

PCO can be treated surgically or with a less invasive method—neodymium-doped yttrium aluminum garnet (Nd:YAG) laser capsulotomy—which is performed to improve visual acuity and obtain a good fundus image [4,6,7]. Nd:YAG laser posterior capsulotomy is a highly safe and painless method compared to surgical capsulotomy that can be applied in outpatient settings [8].

Although Nd:YAG laser posterior capsulotomy is less invasive and easier to perform, complications are possible. Major anterior segment complications include elevated intraocular pressure (IOP), corneal endothelial damage, tyndallization, IOL damage, and iris hemorrhage, while the main posterior segment complications include retinal detachment (RD), vitreous prolapse, cystoid macular edema (CME), and anterior hyaloid rupture [8,9].

In this study, we aimed to investigate the effect of IOLs on the formation of PCO, to evaluate the time elapsed between surgery and Nd:YAG laser capsulotomy, and to determine the efficacy, effectiveness, and complications of capsulotomy in patients who underwent cataract surgery with the phacoemulsification (PE) method and subsequently developed PCO.

Materials and methods

Ethical approval for this study was obtained from the Ethics Committee of Harran University (Jan. 6, 2006, decision no. 4). The patients participating in the study provided informed consent in accordance with the principles of the Declaration of Helsinki. The study included one eye of each of 153 cases (63 males, 90 females) that had undergone cataract extraction and IOL implantation with the endocapsular PE method in our clinic from Aug. 1, 2006, through Aug. 1, 2008, had developed PCO in the postoperative period and underwent Nd:YAG laser capsulotomy. The ages of the cases varied between 36 and 82 years, with a mean of 62.64 (9.72) years (Table 1).

Table 1: Age and gender distribution of cases according to the groups

	IOL type					
	PMMA		Hydrophilic acrylic		Hydrophobic acrylic	
Gender	Male	Female	Male	Female	Male	Female
n	16	23	30	36	17	31
%	33.4	66.6	45.45	54.55	35.41	64.59
Age, mean (SD)	61.12 (10.55)	60.43 (8.00)	61.83 (9.68)	64.75 (7.12)	63.88 (10.27)	62.70 (12.59)

IOL: intraocular lens, PMMA: polymethylmethacrylate, SD: standard deviation

In the eyes that had undergone PE and IOL implantation, a side-entry was made following the induction of local anesthesia. After filling the anterior chamber with viscoelastic material, a 2-mm corneal tunnel incision was made, followed by 5.0–5.5-mm capsulorhexis and hydrodissection. Then, PE was performed with the stop and chop technique. Cortex material was cleaned with irrigation and aspiration. After filling the capsule and anterior chamber with viscoelastic material, a hydrophilic acrylic IOL (Eyecryl 600, biconvex, 6.0–12.5 mm, biconvex design, 5° haptic angle, round-sedged, foldable; India) and a hydrophobic acrylic IOL in 48 (Sensar AR40e, biconvex design, 6–13 mm, 5° haptic angle, sharp-edged, foldable; Advanced Medical Optics, USA). In the remaining 39 patients, before IOL implantation, the corneal incision was enlarged to 5.5 mm, and a polymethylmethacrylate (PMMA) IOL (Clear Vision, biconvex, 5.5–12.5 mm, 5° haptic angle, round-edged; India) was placed into the capsule. The corneal incision was sutured with 2 or 3 10/0 monofilaments. The viscoelastic material was cleaned with irrigation and aspiration, and the anterior chamber entrances were inflated with a balanced eye solution.

The patients were called for controls at the first week, first month, third month, sixth month, 12th month, 24th month, and 48th month after PE surgery.

Patients with decreased visual acuity; those with photophobia, glare, or loss of contrast sensitivity due to PCO; those in which the fundus could not be visualized; and those with diplopia development due to PCO were included in the sample. Cases with uncontrollable IOP, in which the posterior capsule could not be seen (due to pathologies in the cornea or anterior chamber), those with no vision, patients diagnosed with neurological or psychiatric disease, those using drugs (e.g., atropine, pilocarpine, cyclopentolate) to prevent pupillary dilation and accommodation, and those who did not regularly attend their control examinations were excluded.

The cases were divided into the following three groups according to the type of IOL implanted:

- Group 1: PMMA IOL
- Group 2: hydrophilic acrylic IOL
- Group 3: hydrophobic acrylic IOL

Before posterior capsulotomy, the patients underwent a complete eye examination. It was noted when the cases had undergone cataract surgery. Visual acuity was determined using the Snellen chart, and IOP was measured with Goldmann's applanation tonometer. The cornea, anterior chamber, iris, pupil, IOL, posterior capsule, vitreous, and fundus examinations were undertaken with biomicroscopy, if possible, in the presence of PCO.

Before posterior capsulotomy, the eyes of the cases were dilated with 1% tropicamide (Tropamid®, Bilim Pharmaceuticals, Istanbul, Turkey) and 2.5% phenylephrine hydrochloride (Mydfrin®, Alcon Labs, Texas, USA) drops. As a topical anesthetic, 0.5% proparacaine hydrochloride (Alcaine®, Alcon-Couvreur, Puurs, Belgium) was used. Capsulotomies were performed using a Q-switched (Meridian Microruptor V, Berne, Switzerland) Nd:YAG laser device and a capsulotomy lens (Volk® Capsulotomy Lens, USA). The energy level of the laser device was adjusted according to the degree of PCO, and capsulotomies with a diameter of 3–4 mm were created in the posterior capsule center. During each application, starting from the lowest energy value, this value was increased or fixed

according to the potency. After laser capsulotomy, 1% brinzolamide (Azopt®, Alcon Labs, USA) and 1% dexamethasone (Maxidex®, Alcon Labs, USA) were dripped into the eye of each case.

At the end of the first, second, and third hours after the posterior capsulotomy procedure, IOP measurement and biomicroscopic anterior segment examination were performed. If IOP was below 22 mmHg, 1% dexamethasone (Maxidex®) (4x1) was applied, and if between 22 and 25 mmHg, 1% brinzolamide (Azopt®) (2x1) and 1% dexamethasone (4x1) were administered for a week. If IOP was above 25 mmHg, oral acetazolamide (250 mg, 4x1; Diazomid® tablets, Biofarma Istanbul, Turkey) and potassium citrate + potassium bicarbonate (8 mg, 1x1; Kalinor®, Farma-Tek, Istanbul, Turkey) were prescribed, and the patients were called for check-ups after 1 week. The patients were encouraged to attend follow-up evaluations at the first and third months.

In the follow-up examinations, visual acuity was evaluated according to the Snellen chart, IOP was measured with Goldmann applanation tonometry, and examinations of the cornea, anterior chamber, iris, pupil, intraocular lens, posterior capsule, vitreous, and fundus were performed with a biomicroscope. A visual acuity improvement of one line or more on the Snellen chart after capsulotomy was accepted as an increase in visual acuity.

Statistical analysis

The paired *t*-test, chi-square test, and Pearson correlation analysis were performed using the Statistical Package for the Social Sciences v. 11.5 (SPSS, Chicago, IL, USA) software package. Continuous variables that were normally distributed were represented as the mean (standard deviation [SD]), while non-normally distributed continuous variables were represented as the median (min-max). A *P*-value of less than 0.05 was considered significant.

Results

The best-corrected visual acuity (BCVA) scores of the cases before capsulotomy were found to vary between 3 mps and 0.8 mps. After Nd:YAG laser capsulotomy, visual acuity improved in 96.7% of all of the 153 cases, 96.7% of the 39 cases in Group 1, 97% of the 66 cases in the hydrophilic acrylic Group 2, and 98% of the 48 cases in Group 3. Among the five cases whose visual acuity did not improve following capsulotomy, diabetic maculopathy was found in two, myopic retinal degeneration in one, senile macular degeneration in one, and intravitreal hemorrhage in one.

When the BCVA levels of the cases before and after capsulotomy were compared, the mean BCVA increase was 0.3 (0.2) in all the cases, 0.3 (0.2) in Group 1, 0.4 (0.2) in Group 2, and 0.3 (0.2) in Group 3. In the statistical analysis performed with the paired *t*-test, the increase in BCVA was found to be statistically significant ($P<0.05$).

IOP measurements were performed before and after (first hour, second hour, third hour, first week, first month, and third month) Nd:YAG laser capsulotomy. When the IOP levels before capsulotomy and at the third hour were compared, the IOP elevation was less than 3 mmHg in 14.4% of the 153 cases, between 3 and 5 mmHg in 76.5%, and more than 5 mmHg in 9.1%. In Group 1, the IOP elevation was below 3 mmHg in 15.4% of the cases, between 3 and 5 mmHg in 74.4%, and above 5 mmHg in 10.2%, while these rates were determined to be 10.6%, 80.3%, and 9.1%, respectively, in Group 2, and 16.7%, 75%, and 8.3%, respectively, in Group 3. An IOP elevation above 10 mmHg was not detected in any of the cases (Table 2). When the mean IOP measurements of the patients before and after Nd:YAG laser capsulotomy were compared, the mean IOP increase at the third hour was 3.83 (1.81) mmHg in all the cases, 3.84 (1.86) mmHg in Group 1, 3.93 (1.23) mmHg in Group 2, and 3.69 (1.38) mmHg in Group 3. The paired *t*-test results revealed that the post-capsulotomy increase in IOP was significant within the groups ($P<0.001$). However, there was no statistically significant difference in the mean IOP increase between the groups ($P>0.05$).

Table 2: Mean IOP measurements of the cases before and after capsulotomy

IOL type	IOP before capsulotomy	IOP after capsulotomy					
		Hour 1	Hour 2	Hour 3	Week 1	Month 1	Month 3
Group 1	14.48 (3.20)	15.80 (3.10) x	17.17 (2.90) xx	18.33 (3.06) xxx	14.25 (3.08)	14.42 (3.08)	14.42 (3.14)
Group 2	14.06 (3.06)	15.46 (3.14) x	16.87 (3.24) xx	18.01 (3.43) xxx	14.28 (2.87)	14.06 (2.88)	14.01 (2.94)
Group 3	15.04 (2.72)	16.12 (2.86) x	17.50 (3.01) xx	18.72 (3.24) xxx	14.79 (2.66)	14.89 (2.62)	14.90 (2.68)
Total	14.47 (3.01)	15.77 (3.05) x	17.15 (3.09) xx	18.31 (3.27) xxx	14.28 (2.87)	14.41 (2.86)	14.39 (2.94)

x: $P<0.05$ xx: $P<0.01$ xxx: $P<0.001$, IOP: intraocular pressure, IOL: intraocular lens

The mean energy used in all cases that underwent capsulotomy was 2.36 (0.33) mjl/pulse, the total energy was 37.20 (14.70) mjl, and the mean number of shots was 15.92 (6.40). When examined according to the groups, the mean energy, total energy, and mean number of shots were determined as 2.49 (0.43) mjl/pulse, 39.15 (15.70) mjl, and 16.15 (7.20), respectively in Group 1, 2.30 (0.28) mjl/pulse, 37.27 (13.15) mjl, and 16.21 (5.57), respectively in Group 2, and 2.35 (0.30) mjl/pulse, 35.81 (15.90) mjl, and 15.35 (6.87), respectively in Group 3 (Table 3).

Table 3: Mean energy, total energy, and number of laser shots used during capsulotomy

Groups	Number of eyes n (%)	Mean energy (mjl/pulse)	Total energy (mjl)	Number of laser shots
Group 1	39 (25.5)	2.49 (0.43)	39.15 (15.70)	16.15 (7.20)
Group 2	66 (43.2)	2.30 (0.28)	37.27 (13.15)	16.21 (5.57)
Group 3	48 (31.3)	2.35 (0.30)	35.81 (15.90)	15.35 (6.87)
Total	153 (100)	2.36 (0.33)	37.20 (14.70)	15.92 (6.40)

When the relationship between total energy used in capsulotomy and IOP levels was examined, the total energy used was 22.04 (10.11) mjl in 21 cases with a post-capsulotomy IOP elevation <3 mmHg, 35.99 (8.52) mjl in 118 cases with a post-capsulotomy IOP elevation of 3–5 mmHg, and 71.07 (10.59) mjl in 14 cases with a post-capsulotomy IOP elevation >5 mmHg (Table 4).

Table 4: Total energy used according to IOP increase after capsulotomy

IOP increase	Group 1 Total energy (mjl)	Group 2 Total energy (mjl)	Group 3 Total energy (mjl)	Whole cohort Total energy (mjl)
<3 mmHg	19.66 (01.75)	22.14 (4.74)	24.62 (16.04)	22.04 (10.11)
3-5 mmHg	38.41 (08.32)	36.05 (8.37)	33.97 (8.50)	35.99 (8.52)
>5 mmHg	73.75 (12.09)	66.83 (8.08)	74.75 (11.06)	71.07 (10.59)

IOP: Intraocular pressure

In the correlation analysis between the mean IOP increase and the total energy levels used in all the cases and groups, it was observed that IOP elevation increased

significantly as the total energy used increased (P<0.001, r=867); however, there was no statistically significant difference between the groups (P>0.05).

The time between cataract surgery and Nd:YAG laser capsulotomy was 10.54 (9.25) months in all cases, 6.29 (4.91) months in Group 1, 7.81 (4.35) months in Group 2, and 17.7 (12.35) months in Group 3. Accordingly, it was determined that capsulotomy was performed earliest in the cases that underwent PMMA IOL implantation and latest in those that underwent hydrophobic IOL implantation, while the cases in the hydrophilic IOL group required capsulotomy later than the PMMA IOL group and earlier than the hydrophilic IOL group. There was a significant difference between the three groups in relation to time elapsed between cataract surgery and Nd:YAG laser capsulotomy (P<0.001).

After capsulotomy, IOL damage was detected in six (3.9%) cases in the whole cohort—three (7.7%) cases in Group 1, two (3%) cases in Group 2, and one (2%) case in Group 3. In addition, in the post-capsulotomy period, three patients had clinically significant macular edema, and one patient with DM developed intravitreal hemorrhage. Complications such as iris hemorrhage, vitreous prolapse, and RD were not observed in any of our cases after capsulotomy.

Discussion

Despite all the developments in cataract surgery, PCO remains one of the most important complications of cataract surgery. It has been reported that the incidence of PCO associated with standard cataract surgery ranges from 5% to 50% [5]. Current studies show that Nd:YAG laser capsulotomy is widely used in the treatment of PCO and significantly improves visual function in these patients [1,5,9,10]. Various studies have found a substantial increase in visual acuity after Nd:YAG laser capsulotomy performed in cases with PCO [6]. In the current study, the mean visual acuity increase was 0.4 in all cases.

In the literature, following Nd:YAG laser capsulotomy, visual acuity was reported not to have increased in 8.3% of cases by Menon et al. [11], 6.1% by Dawood et al. [12], and 2.5% by Javed et al. [13], which were all due to secondary eye events, such as maculopathy, diabetic retinopathy, and myopic retinal degeneration [11–13]. In our study, there was no visual acuity improvement in 3.3% of the cases after Nd:YAG laser capsulotomy. This lack of improvement was determined to be associated with diabetic retinopathy in two cases, myopic retinal degeneration in one, maculopathy in one, and intravitreal hemorrhage in one.

Studies have shown an increase in IOP after Nd:YAG laser posterior capsulotomy, which has been attributed to several mechanisms. First, outflow is prevented by the accumulation of capsular residues and inflammatory cells, blood elements, fibrin, and high–molecular-weight proteins in the inner wall of the trabecular mesh and Schlemm canal as a result of the Nd YAG laser capsulotomy procedure, leading to increased IOP [14]. Other mechanisms underlying IOP increase include the vitreous moving forward and causing pupillary block, laser shock waves damaging endothelial cells in the trabecular meshwork and resulting in edema, and trabecular cells being damaged by liberated inflammatory mediators or directly by the laser procedure itself [15,16].

In various studies, it has been reported that the mean increase in IOP is between 1.2 and 9.1 mmHg after Nd:YAG laser capsulotomy. In the literature, the mean IOP increase after capsulotomy was reported as 1.2 mmHg by Ge et al. [17], 2.1 mmHg by Cai et al. [18], 2.5 mmHg by Seong et al. [19], 3.0 mmHg by Maden et al. [20], 3.6 mmHg by Kraff et al. [16], 4.2 mmHg by Pollack et al. [21], 4.4 mmHg by Esgin et al. [22], and 9.1 mmHg by Gartaganis et al. [23]. In our study, the mean IOP increase after capsulotomy was found to be 3.8 mmHg.

Studies have shown that IOP elevation resulting from Nd:YAG laser decreases to pre-capsulotomy values within 24 hours to 1 week, through drugs used [18,24]. Our study determined that IOP decreased to the values before capsulotomy (i.e., baseline values) at the end of 1 week.

The relationship between the increase in IOP due to Nd:YAG laser capsulotomy and the total amount of energy used has also been previously investigated. Kraff et al. [16], Esgin et al. [22], and Leys et al. [25] reported no significant relationship between the increase in IOP and the total energy used, while Shetty [26] et al., Cumurcu et al. [27], and Rahul et al. [28] found a significant relationship between the increase in IOP and the total energy used. In the current study, the mean total energy used was 37.2 (14.7) mjl, and the mean energy used in the patients with an IOP increase over 5 mmHg was determined to be 71 (10) mjl, indicating a significant correlation between the increase in IOP and the total energy used.

According to previous studies, the time between surgery and Nd:YAG laser capsulotomy varies between 1 month and 38 months [21,29,30]. In our cases, this time interval was between 1 and 48 months, which is consistent with other studies.

Ram et al. [31] investigated the effect of PMMA, silicone, acrylic hydrophilic, and hydrophobic IOLs on PCO and found that the patients with PMMA IOLs developed PCO at a higher rate than the remaining groups over a 2–4-year follow-up period.

Suh et al. [32] evaluated the effect of hydrophilic and hydrophobic acrylic IOLs on PCO. Over the 3-year follow-up of cases, the authors reported that PCO developed in 20.3% of those who had undergone hydrophilic acrylic IOL implantation and 6.8% of those who had undergone hydrophobic acrylic IOL implantation, and they performed Nd:YAG laser capsulotomy in all of the cases that developed PCO. In another study comparing hydrophilic and hydrophobic acrylic IOLs, Kaya et al. [33] reported that the patients with hydrophilic acrylic IOLs had a higher rate of PCO development than those with hydrophobic acrylic IOLs during the 12-month follow-up period. In our study, we divided the patients into three groups according to the type of IOL implanted after cataract surgery. The mean time between surgery and Nd:YAG laser capsulotomy was 6.29 months in the PMMA IOL group, 7.81 months in the hydrophilic acrylic IOL group, and 17.7 months in the hydrophobic acrylic IOL group. These values are in agreement with previous studies.

PMMA and hydrophilic IOLs accelerate the proliferation of lens epithelial cells (LECs) due to their biomaterial structure. With its bioadhesive properties, the hydrophobic acrylic IOL adheres well to the lens capsule and

prevents the migration of LECs [34,35]. In addition to the biomaterial structure of this IOL, the edge characteristics also affect the formation of PCO. The sharp-cut edges found in this IOL create bends, preventing the migration of LECs and reducing the rate of PCO development [36,37]. In our study, the late appearance of PCO in Group 3 compared to the other two groups can be explained by the bioadhesive properties and sharp edges of the hydrophobic acrylic IOL used.

Studies have reported that RD occurs in 0.21–2.6% of cases after Nd:YAG laser capsulotomy [21,25,38]. It has been suggested that the incidence of RD increases after Nd:YAG capsulotomy in myopic patients, and that surgeons exercise greater caution and should use minimum energy when performing their surgeries. In contrast, Javed et al. [13], Şimsek et al. [39], and Khanzada et al. [40] found no RD development after Nd:YAG laser capsulotomy. We also did not observe RD development in any of our cases after capsulotomy.

In the literature, the rate of CME development following Nd:YAG laser capsulotomy was reported as 0.5% by Dawood et al. [12] and 3% by Raza et al. [41], while Esgin et al. [22] and Anil et al. [24] did not find CME development in any of their patients after this surgery. In the current study, 1.9% of the patients developed clinically significant CME. This was previously attributed to the release of prostaglandins as a result of damage to the vitreous after capsulotomy [42].

In previous studies, GIL damage following Nd:YAG laser capsulotomy was reported at a rate of 17.1% by Özkağnıcı et al. [43], 11.5% by Esgin et al. [22], 7.8% by Rahul et al. [28], 5.4% by Khanzada et al. [40] 3.3% by Javed et al. [13], and 0.5% by Dawood et al. [12]. Consistent with the literature, we determined that 3.9% of our patients had IOL damage after this surgery.

Conclusion

PCO is a complication that causes symptoms such as decreased visual acuity, photophobia, and decreased contrast sensitivity after cataract surgery. Many factors affect the development of PCO, such as DM and the type of IOL implanted. Based on our results, we recommend the use of hydrophobic acrylic IOLs during this surgery, since they result in less PCO development.

Although this is a highly safe and painless method compared to surgical capsulotomy that can be applied under outpatient clinic conditions, it also has certain complications, including elevated IOP, RD, CME, IOL damage, and vitreous prolapse. To eliminate the risk of most of these complications, it is necessary to minimize the energy used during the laser procedure.

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