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# COMPLICATIONS Nd:YAG LASER POSTERIOR CAPSULOTOMY AFTER PHACOEMULSIFICATION: A COMPARISON BETWEEN CRUCIATE AND CIRCULAR TECHNIQUES

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## ABSTRACT

**Objective:** To determine and compare the incidence rates of complications and adverse events following Nd:YAG laser posterior capsulotomy using cruciate and circular techniques after phacoemulsification.

**Subjects and Methods:** This randomized interventional comparative study conducted at Tra Vinh General Hospital from June to August 2022. Patients diagnosed with posterior capsule opacification (PCO) at least six months after phacoemulsification were randomly assigned to undergo Nd:YAG laser posterior capsulotomy using either the cruciate or circular technique.

**Results:** The total energy used in the cruciate laser group was lower than in the circular laser group (69.43 ± 13.55mJ versus 123.56 ± 27.11mJ). No intraoperative complications were recorded in either the cruciate or circular Nd:YAG laser groups. Early postoperative complications included conjunctival hyperemia, corneal edema, and intraocular pressure elevation. There was no significant difference in the complication rates between the two techniques. All complications resolved completely within one month. No cases of cystoid macular edema, retinal detachment, uveitis, or macular hole were observed.

**Conclusion:** Both cruciate and circular Nd:YAG laser posterior capsulotomy techniques are safe and effective after phacoemulsification. Although the circular technique requires higher total laser energy, postoperative complication rates are comparable between the two techniques.

***Keywords:*** Posterior capsule opacification, Nd:YAG laser capsulotomy, complications, cruciate technique, circular technique.

## 1. INTRODUCTION

Posterior capsular opacification (PCO) is the most common late complication following cataract surgery[1]. PCO develops due to the aberrant proliferation and differentiation of cells on the posterior capsule[1]. After phacoemulsification, the onset of posterior capsular opacification varies from several months to several years. Currently, the most common treatment for PCO is Nd:YAG laser capsulotomy, aimed at creating an opening in the posterior capsule. Thereby restoring transparency along the visual axis and improving visual function for patients[1,2]. Various shapes of capsulotomy, such as the Christmas tree or hexagonal forms, have been described. However, this study focuses exclusively on cruciate and circular opening techniques. Nd:YAG laser posterior capsulotomy is regarded as a safe and effective procedure. However, the sight-threatening complications such as cystoid macular edema and retinal detachment may still occur[2]. A common complication of Nd:YAG laser capsulotomy is damage to the intraocular lens (IOL)[2,5]. In clinical ophthalmic practice, the circular capsulotomy is often preferred. It helps avoid damaging the IOL at the central position. If damage does occur at the periphery, it has less impact on visual function post-treatment. In contrast, performing a cruciate capsulotomy requires careful and precise aiming of the laser beam. Because damage to the IOL at the central position can significantly impair the patient's visual function. Several studies in Vietnam have shown promising results in the treatment of PCO with Nd:YAG laser. However, the optimal and safest capsulotomy pattern under local clinical conditions in Tra Vinh remains unclear. Therefore, we conducted this study at Tra Vinh General Hospital with the objective of determining the incidence of complications and adverse events following posterior capsulotomy after Phaco surgery between the cruciate and circular Nd:YAG laser techniques.

## 2. SUBJECTS AND METHODS

### 2.1. Research subjects

Inclusion criteria: Patients diagnosed with posterior capsular opacification (PCO) occurring at least 6 months after phacoemulsification surgery, presenting with symptoms affecting daily activities, had best-corrected visual acuity ≤ 5/10, and who consent to participate in the study.

Exclusion criteria: Patients with acute ocular surface infections, central corneal scarring, corneal edema or dystrophy, glaucoma associated with elevated intraocular pressure, history or suspicion of cystoid macular edema, retinal tears, or those diagnosed with systemic diseases such as hypertension, diabetes mellitus, heart failure, etc., that have resulted in ocular complications. Patients who do not consent to

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participate in the study are also excluded.

### 2.2. Research methods

***Research design:*** This is an interventional study with a comparative analysis between two groups: (1) the group treated with Nd:YAG laser using the cruciate technique (referred to as the cruciate laser group), and (2) the group treated with Nd:YAG laser using the circular technique (referred to as the circular laser group).

***Sampling method:*** All patients diagnosed with posterior capsular opacification following phacoemulsification who presented for examination and treatment at Tra Vinh general hospital from June 2022 to August 2022 and who met the inclusion and exclusion criteria were recruited. Patients were randomly assigned into two groups using a lottery method: those drawing even-numbered tickets were allocated to the cruciate laser group, while those with odd-numbered tickets were allocated to the circular laser group. The process continued until 88 eyes were enrolled in each group.

***Sample size:*** 176 eyes (88 eyes in the cruciate laser group, 88 eyes in the circular laser group).

***Research content:*** The incidence rates of complications and adverse events following posterior capsulotomy after phaco surgery between two techniques: cruciate and circular Nd:YAG laser. The research was conducted from June 2022 to August 2022 at Tra Vinh General Hospital.

***Data processing and analysis:*** Data were entered and analyzed using Stata MP version 16.0 statistical software.

***Resarch ethics:*** The study protocol was approved by the ethics committee of the University of Medicine and Pharmacy, Ho Chi Minh City (Decision No. 554/HĐĐĐ-ĐHYD dated June 9, 2022), as well as by the management board and the department of ophthalmology at Tra Vinh general hospital prior to implementation. All patients who agreed to participate in the study received clear explanations regarding the study's objectives and potential complications.

## 3. RESULTS

### 3.1. Laser energy used

**Table 1. Laser energy used**

| | Severity of opacification | Cruciate laser | Circular laser | Total | p* |
|---|---|---|---|---|---|
| Energy per pulse (mJ/pulse) | Grade I (1) | 1.34±0.09 | 1.31±0.08 | 1.33±0.08 | 0.315 |
| | Grade II (2) | 1.45±0.11 | 1.44±0.10 | 1.44±0.11 | 0.276 |
| | Grade III (3) | 1.80±0.15 | 1.74±0.16 | 1.77±0.17 | 0.126 |
| | Total | 1.54±0.22 | 1.50±0.18 | 1.52±0.20 | 0.09 |
| | p* | $p_{21}$ <0.01 | $p_{32}$ <0.001 | $p_{21}$ <0.01 | |
| | | $p_{32}$ <0.001 | $p_{32}$ <0.001 | $p_{21}$ <0.001 | |
| Total energy (mJ/eye) | Grade I (1) | 61.39±6.20 | 96.91±14.70 | 77.97±21.17 | <0.001 |
| | Grade II (2) | 64.76±9.94 | 121.45±24.26 | 93.38±33.97 | <0.001 |
| | Grade III (3) | 82.97±9.94 | 137.56±29.39 | 109.63±35.53 | <0.001 |
| | Total | 69.43±13.55 | 123.56±27.11 | 96.32±34.51 | <0.001 |
| | p* | $p_{21}$ <0.05 | $p_{32}$ <0.05 | $p_{21}$ <0.01 | |
| | | $p_{32}$ <0.001 | $p_{32}$ <0.01 | $p_{21}$ <0.05 | |

**: t test*

Comment: The mean energy per pulse was 1.52 ± 0.20 mJ and increased progressively with the severity of posterior capsule opacification; this difference was statistically significant (p < 0.01). The mean total energy used was 96.32 ± 34.51 mJ per eye and also increased with the severity of posterior capsule opacification, with a statistically significant difference (p < 0.05). There was no statistically significant difference in mean energy per pulse between the cruciate laser group and the circular laser group (p = 0.09 > 0.05). The circular laser group required significantly higher total energy than the cruciate laser group (123.56 ± 27.11 mJ vs. 69.43 ± 13.55 mJ, p < 0.001).

### 3.2. Intraocular pressure before treatment

Comment Table 2: There were no cases of elevated intraocular pressure prior to treatment. The mean intraocular pressure before treatment was 17.56 ± 1.13 mmHg (cruciate laser group: 17.47 ± 1.14 mmHg; circular laser group: 17.67 ± 1.13 mmHg). The difference in intraocular pressure between the two groups was not statistically significant (p = 0.143 > 0.05).

**Table 2. Intraocular pressure before treatment**

| Cruciate laser (n, %) | Circular laser (n, %) | Total | p |
|---|---|---|---|
| Increased | | | 1.000* |
| 0 (0) | 0 (0) | 0 (0) | |
| Normal | | | |
| 80 (100) | 79 (100) | 159 (100) | |
| $\bar{X}$ ± SD (Min - max) | | | |
| 17.47±1.14 (15.6 – 20.6) | 17,67±1.13 (15.6 – 20.1) | 17.56±1.13 (15.6 – 20.6) | 0.143** |

**: χ2 test, **: t test*

### 3.3. Subjective symptoms after treatment

**Table 3. Subjective symptoms after 3 months treatment**

| Subjective symptoms | Cruciate laser (n, %) | Circular laser (n, %) | p |
|---|---|---|---|
| Yes | 28 (35.00) | 26 (32.91) | 0.781 |
| Photophobia | 5 (6.25) | 5 (6.33) | |
| Floaters | 21 (26.25) | 18 (22.78) | |
| Headache | 2 (2.50) | 3 (3.80) | |
| None | 52 (65.00) | 53 (67.09) | |
| Total | 80 (100) | 79 (100) | |

Comment: After 3 months, subjective symptoms were observed in 35% of eyes in the cruciate laser group and 32.91% of eyes in the circular laser group. The difference between the two groups was not statistically significant according to the $\chi^2$ test (p = 0.781 > 0.05). The most common subjective symptom was floaters (cruciate laser group: 26.25%; circular laser group: 22.78%). The incidence of glare or headache was low.

### 3.4. Complications during treatment

**Table 4. Complications during treatment**

| | Cruciate laser (n, %) | Circular laser (n, %) | Total |
|---|---|---|---|
| Posterior capsular rupture | 0 (0) | 0 (0) | 0 (0) |
| Iris injury | 0 (0) | 0 (0) | 0 (0) |
| Hyphema | 0 (0) | 0 (0) | 0 (0) |
| Intraocular lens damage | 0 (0) | 0 (0) | 0 (0) |

Comment: No cases of complications during treatment.

### 3.5. Post-treatment complications

**Table 5. Changes in intraocular pressure after treatment**

| Time | Cruciate laser | | Circular laser | |
|---|---|---|---|---|
| | IOP (mmHg) | p* | IOP (mmHg) | p* |
| Before treatment | 17.47±1.14 | 1.000 | 17.67±1.13 | 1.000 |
| 1 day | 19.55±1.44 | <0.001 | 20.21±1.51 | <0.001 |
| 1 week | 18.49±1.47 | <0.001 | 19.09±1.54 | <0.001 |
| 1 month | 17.80±1,29 | >0.05 | 17.94±1.42 | >0.05 |
| 3 months | 17.41±1.22 | >0.05 | 17.69±1.34 | >0.05 |
| $P_{cruciate-circular}$ | $p_{T1}<0.01$ $p_{T2}<0.05$, $p_{T3}>0.05$ $p_{T4}>0.05$ | | | |

**: t test*

Comment: Mean intraocular pressure (IOP) at 1 day and 1 week post-treatment was significantly higher than baseline in both the cruciate laser and the circular laser (p < 0.001). At 1 and 3 months, mean IOP did not differ significantly from baseline values (p > 0.05). The circular laser group exhibited significantly higher IOP than the cruciate laser group at 1 day and 1 week post-treatment. No significant difference in IOP between the two groups was observed at 1 and 3 months (p > 0.05).

### 3.6. Post-treatment complications

**Table 6. Post-treatment complications**

| | Cruciate laser (n=80) | | | | Circular laser (n=79) | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 day (n, %) | 1 week (n, %) | 1 month (n, %) | 3 months (n, %) | 1 day (n, %) | 1 week (n, %) | 1 month (n, %) | 3 months (n, %) |
| Conjunctival hyperemia | 20 (25.00) | 13 (16.25) | 0 (0) | 0 (0) | 19 (24.05) | 11 (13.92) | 0 (0) | 0 (0) |
| Corneal edema | 18 (22.50) | 11 (13.75) | 0 (0) | 0 (0) | 19 (24.05) | 13 (16.46) | 0 (0) | 0 (0) |
| Elevated intraocular pressure | 7 (8.75) | 2 (2.50) | 0 (0) | 0 (0) | 13 (16.46) | 4 (5.06) | 0 (0) | 0 (0) |
| Cystoid macular edema | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) |
| Uveitis | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) |
| Macular hole | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) |
| Retinal detachment | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) |

Comment: Post-treatment complications observed at 1 day and 7 days included conjunctival hyperemia, corneal edema, and elevated intraocular pressure (IOP). The rates of conjunctival hyperemia at 1 day and 7 days were 25.00% and 16.25% in the cruciate laser group and 24.05% and 13.92% in the circular laser group; corresponding

rates of corneal edema were 22.50% and 13.75% versus 24.05% and 16.46%, respectively. Elevated IOP occurred in 8.75% and 2.50% of eyes in the cruciate laser group and in 16.46% and 5.06% in the circular laser group. All complications resolved completely by 1 and 3 months. The incidence of elevated IOP was significantly higher in the circular laser group at 1 day post-treatment ($p < 0.05$), but the difference was not significant at 7 days. No significant differences were observed between the two groups in the rates of conjunctival hyperemia or corneal edema ($p > 0.05$).

## 4. DISCUSSION

### 4.1. Laser energy usage

This study found no significant difference in the average energy per pulse between the cruciate laser group and the circular laser group (1.54 ± 0.22 mJ/pulse vs. 1.50 ± 0.18 mJ/pulse; p=0.09 >0.05). However, the total treatment energy used in the cruciate laser group was significantly lower than in the circular group (69.43 ± 13.55 mJ vs. 123.56 ± 27.11 mJ), with a statistically significant difference (p<0.001). Thus, the higher energy usage in the circular laser group can be attributed to the greater number of pulses required by the circular capsulotomy technique. Previous studies comparing the techniques of posterior capsulotomy using Nd:YAG laser in circular and cruciate patterns have consistently reported that the circular mode requires higher total energy due to an increased number of laser pulses [3],[4]. In the study by Kim et al., the average laser energy per pulse was found to be 1.91 ± 0.31 mJ in the cruciate group and 1.97 ± 0.24 mJ in the circular group; this difference was not statistically significant (p=0.102 >0.05). However, the total mean energy used in the cruciate group (72.12 ± 28.65 mJ) was significantly lower than that of the circular group (195.88 ± 120.06 mJ; p<0.001)[3].

### 4.2. Subjective symptoms

After laser treatment, residual capsular fragments may float in the vitreous cavity, causing vitreous opacities that manifest as floaters. This is a common symptom that often appears following the procedure but tends to improve gradually over time. In the study by Nguyen Van Lanh, 12 out of 72 eyes (16.7%) reported experiencing floaters one week after treatment; however, this rate decreased from one month onwards [5]. We did not find any other studies abroad that reported the incidence of vitreous opacities following laser treatment, suggesting that this symptom may not be a prominent or significantly bothersome issue for patients after the procedure.

### 4.3. Complications during treatment

Common complications of Nd:YAG laser posterior capsulotomy include intraocular lens damage, hyphema, and iris injury [2]. The impact of Nd:YAG laser on the IOL can vary in severity, the most severe is IOL fracture. The causes may relate to factors such as the laser energy used, the IOL material, the patient's cooperation. Moreover, other contributing factors include the surgeon's experience. In this study, there were no cases of treatment-related complications such as posterior capsule rupture, iris injury, hyphema or IOL damage. This may be attributed to the reasonable energy setting per pulse used in this study. Additionally, preventative measures were proactively implemented before the laser procedure, leading to good patient cooperation and thus minimizing the occurrence of such complications.

### 4.4. Post-treatment complications

#### *4.4.1 Intraocular pressure changes after treatment*

In this study, all eyes received 0.5% apraclonidine one hour prior to surgery to prevent intraocular pressure (IOP) spikes, followed by acetazolamide 0.25g (two tablets/day) for two days postoperatively. The pattern of IOP changes was similar in both the cruciate and circular laser groups: IOP peaked at 1 day post-treatment, showing a statistically significant increase compared to baseline (p<0.001), and then decreased thereafter. At 1 week, as well as at 1 month and 3 months post-procedure, mean IOP values did not differ significantly from pre-treatment levels (p>0.05).

According to Vu Tuan Anh, the mean IOP increased at 1 hour and 1 day after laser compared to baseline; however, this difference was not statistically significant (p>0.05) [6]. Only one eye exhibited elevated IOP (24 mmHg) one hour after treatment. At 1 week, 1 month, and 3 months, all 50 eyes (100%) maintained stable IOP, with no significant changes at these time points (p>0.05) [6]. In the study by Nguyen Van Lanh, transient IOP elevation was observed in 4 eyes (5.6%) within the first hour post-laser. However, IOP returned to normal at all subsequent follow-up visits [5]. Similarly, Dhakne et al. reported IOP elevation in 4 out of 64 eyes (6.25%), which was successfully managed with brimonidine 1% eye drops twice daily for one week [7].

#### *4.4.2. Corneal edema*

In our study, the incidence of corneal edema at 1 day and 1 week postoperatively in the cruciate laser group was 22.50% and 13.75%, while in the circular laser group, the corresponding rates were 24.05% and 16.46%. Due to time constraints and limited research facilities, our study did not assess corneal endothelial cell damage. Kim et al. reported a mean endothelial cell loss of 69.9±201.3 cells/mm$^2$ in the cruciate laser group and 45.0±269.3 cells/mm$^2$ in the circular laser group [3],[4]. However, the difference between the two groups was not statistically significant (p = 0.740 > 0.05) [3],[4].

#### *4.4.3. Retinal complications*

In this study, no patients experienced complications related to retinal tears or detachment. This finding is consistent with the study conducted by Nguyen Van Lanh [5]. Retinal tears and detachment are recognized complications of Nd:YAG laser capsulotomy. It is estimated that the risk of retinal detachment increases fourfold following laser treatment. According to Khan B., retinal detachment occurred in 2 out of 437 eyes (0.45%) during post-treatment follow-up [8].

#### *4.4.5. Cystoid macular edema (CME)*

According to the literature, the incidence of CME following Nd:YAG laser capsulotomy ranges from 0% to 2.3% [1],[2]. In our study, there were no cases of CME, which may be attributed to the relatively long intervals between phacoemulsification and posterior capsulotomy in both the cruciate laser group (35.62 ± 9.35 months) and the circular laser group (34.87 ± 12.37 months). This finding differs from that of Nguyen Van Lanh, who reported 3 cases (4.2%) of CME detected at one week after laser treatment [5]. Similarly, Das et al. found CME in 2% of eyes at both day 1 and week 1 after Nd:YAG laser capsulotomy following phacoemulsification [8].

#### *4.4.6. Other complications*

In this study, no cases of uveitis were observed following Nd:YAG laser capsulotomy. Similarly, Nguyen Van Lanh also reported no incidents of uveitis [5]. In contrast, Vu Tuan Anh documented an incidence of anterior uveitis ranging from 1.1% to 4.3% after treatment [6], while

Borgohain observed anterior uveitis in 19% of patients after laser capsulotomy [9]. No cases of macular hole were detected in our study after Nd:YAG laser capsulotomy. In Nguyen Van Lanh's study, one case of macular hole was reported post-laser treatment [5]. According to the literature, macular hole is considered a relatively rare complication following posterior capsulotomy.

**4.5. Clinical implications**

From a clinical perspective, the cruciate technique may be advantageous in cases where minimizing total laser energy is desired. However, both techniques demonstrate comparable safety profiles and can be selected based on surgeon preference and individual patient characteristics.

**4.6. Limitations**

This study has several limitations. Corneal endothelial cell density and macular OCT were not routinely evaluated due to limited resources. In addition, the follow-up duration may have been insufficient to detect rare late-onset retinal complications. Future studies with longer follow-up and advanced imaging are warranted.

## 5. CONCLUSIONS

The most common postoperative complications noted at days 1 and 7 included conjunctival injection, corneal edema, and elevated intraocular pressure. All complications resolved completely by 1 month and 3 months postoperatively. Both cruciate and circular Nd:YAG laser posterior capsulotomy techniques are safe and effective following phacoemulsification. Although the circular technique requires higher total laser energy, postoperative complication rates are comparable, and all observed complications are transient and self-limiting.

## RECOMMENDATIONS

In the future, longer follow-up studies are needed. Comprehensive equipment, such as specular microscopes should be used to count corneal endothelial cells. This will help evaluate endothelial

cell damage before and after Nd:YAG laser. Additionally, extended follow-up studies are necessary to assess long-term complications, especially those involving the retina.

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