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ABSTRACT

of the dissertation for the degree of Doctor of Philosophy

PREVENTION AND TREATMENT OF GLAUCOMA RESULTING FROM SILICONE OIL TAMPONADE OF THE VITREOUS CAVITY

Specialty: 3219.01 – “Eye diseases”

Field of Science: Medical Sciences

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Baku – 2026

The work was performed at the Department of Ophthalmic Medical Expertise of the National Ophthalmology Centre named after Academician Zarifa Aliyeva.

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Dissertation council FD 1.03 of Supreme Attestation Commission under the President of the Republic of Azerbaijan operating at National Ophthalmology Centre named after Academician Zarifa Aliyeva

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GENERAL CHARACTERISTICS OF THE STUDY

Relevance of the Study. Retinal detachment is one of the most complex ocular pathologies and is characterized by a sometimes unfavorable prognosis. Vitrectomy is considered one of the main treatment methods for rhegmatogenous and tractional retinal detachments, enabling a stable anatomical outcome to be achieved in the majority of patients[1]. In the treatment of rhegmatogenous retinal detachments complicated by proliferative vitreoretinopathy, as well as complex tractional and tractional-rhegmatogenous retinal detachments, vitrectomy is performed with silicone oil tamponade of the vitreous cavity[2].

Silicone oil (polydimethylsiloxane) is a polymeric compound that was first proposed by Cibis P.A. in 1962 as a substance for vitreous cavity tamponade. Over the past 50 years, it has been widely used in vitreoretinal surgery[3].

The advantages of silicone tamponade include: the ability to provide long-term and more complete tamponade of the vitreous cavity; the absence of a requirement for the patient to maintain a specific head position postoperatively; the transparency of the tamponade medium, which allows monitoring of the fundus after surgery and, if necessary, performing retinal laser coagulation on an

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outpatient basis; and relatively good visual acuity during the tamponade period (for this reason, silicone tamponade is performed on the only seeing eye)[1, 2, 4, 5]. In the treatment of vitreoretinal pathology, the duration of silicone tamponade varies over a wide range to achieve a stable outcome with minimal risk of complications. In various studies, the duration of silicone tamponade has been reported to range from one month to permanent tamponade [6, 7, 8].

Despite the considerable advantages of silicone endotamponade, the risk of certain complications occurring at various postoperative stages remains inevitable.

These complications include increased intraocular pressure (IOP), secondary glaucoma, cataract, development of keratopathy, emulsification of silicone oil, and its penetration into the subretinal, suprachoroidal, and subarachnoid spaces. In addition, the literature notes that silicone oil may exert a direct toxic effect on retinal cells[9].

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The pathogenesis of many complications of silicone oil tamponade still remains uninvestigated.

The development of glaucoma resulting from silicone oil tamponade depends on various factors, particularly the duration of the tamponade. Early on, Cibis P.A. demonstrated that the incidence of IOP elevation in eyes with silicone endotamponade reaches 56% eight months after silicone injection.

According to modern data, IOP elevation is observed in 29.4% of cases when silicone is removed within 2 months, in 33.3% when removed between 2 and 6 months, and in 64.3% when removed after 6 months[10].

In addition to glaucomatous optic neuropathy, the potential direct toxic effect of silicone oil on the optic nerve has been proven in in vitro studies[11]. Literature also reports that silicone oil exerts a direct toxic effect on retinal cells[12].

The pathogenesis of many complications of silicone oil tamponade remains unstudied and therefore continues to attract high attention. The development of glaucoma resulting from silicone oil tamponade is one of the main factors limiting the use of silicone oil in vitreoretinal surgery.

Thus, given the necessity of the widespread use of silicone oil in modern vitreoretinal surgery, the problem of preventing and treating elevated IOP during tamponade is also one of the pressing issues in ophthalmology.

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Object and subject of the study.

The present work is a clinical study. The research included retrospective and prospective data from 443 eyes of 427 patients who underwent pars plana vitrectomy at the "Diabetic Eye Complications" and "Vitreoretinal Eye Surgery" departments of the National Ophthalmology Centre named after Academician Zarifa Aliyeva. Patients were divided into two groups according to the method of vitreous cavity tamponade. The first – main – group consisted of patients with silicone oil tamponade, while the second – control – group included patients with expansive gas tamponade.

The exclusion criteria for the study were as follows: neovascularisation of the iris and anterior chamber angle, ocular trauma (traumatic retinal detachments), and a history of primary glaucoma.

Aims of the Study: Prevention of glaucoma induced by silicone oil endotamponade and selection of optimal treatment methods based on pathogenetic mechanisms.

Objectives of the Study.

1. Determination of the frequency of persistent intraocular pressure elevation and secondary glaucoma development after pars plana vitrectomy with silicone oil tamponade of the vitreous cavity.

2. Identification of risk factors for the development of secondary glaucoma in patients following vitrectomy with silicone oil tamponade of the vitreous cavity.

3. Determination of the optimal timing for silicone oil removal, taking into account silicone oil emulsification and its migration into the anterior chamber.

4. Evaluation of the macular ganglion cell layer thickness using spectral-domain OCT (Spectral OCT) and investigation of its effect on final visual acuity.

5. Determination of optimal conservative and surgical treatment methods for patients with secondary glaucoma resulting from silicone endotamponade.

Main provisions submitted for defence:

1. The incidence of secondary glaucoma following pars plana vitrectomy is higher in surgeries performed with silicone oil tamponade compared to those with expansive gas tamponade.
2. Spectral OCT has high diagnostic value for the early detection of emulsified silicone oil in the anterior chamber angle and the posterior pole of the eye, as well as for monitoring the condition of the macular region and the thickness of the retinal ganglion cell layer to predict the functional outcomes of vitreoretinal interventions.
3. The risk factors for silicone endotamponade are as follows: the duration of the tamponade, low viscosity of the silicone oil (1000 cSt), and the presence of significant proliferation.
4. In the treatment of refractory secondary glaucoma resulting from silicone oil tamponade, implantation of an Ahmed valve is an effective method for regulating intraocular pressure.

Scientific Novelty:

1. For the first time, using anterior segment spectral OCT to detect the presence of emulsified silicone oil in the anterior chamber angle at an early stage.
2. For the first time, application of anterior segment spectral OCT in the postoperative period to assess the thickness of the macular ganglion cell layer of the retina in order to predict the patient’s final visual acuity.
3. For the first time, the effect of relaxing retinectomy on intraocular pressure was investigated in proliferative diabetic retinopathy complicated by tractional retinal detachment.

Theoretical and Practical Significance of the Study

The risk factors for IOP elevation associated with silicone oil tamponade of the vitreous cavity, as well as the predictive factors for final visual acuity in patients undergoing pars plana vitrectomy, have been investigated. Based on these factors, preventive measures aimed at the early detection and prevention of secondary glaucoma have been developed, which, in turn, will significantly improve the visual outcomes for patients who have undergone vitrectomy with silicone oil tamponade.

Methods of the Study

Patients underwent standard and specialised ophthalmic examinations, including visual acuity testing, non-contact tonometry (Non-Contact Tonometer, Tomey, USA), biomicroscopy of the anterior and posterior segments of the eye, and optical coherence tomography (Cirrus HD-OCT, Carl Zeiss Meditech, Germany).

Patients' visual acuity was determined using a decimal grading system with charts. For the reliability of statistical analysis, visual acuity was subsequently converted to the decimal logarithm of the minimum angle of resolution (LogMAR) values.

Postoperatively, patients were examined daily during the first week, then at weekly intervals for one month, if necessary within two months, subsequently monthly for one year, and in the second year, at three-month intervals.

Statistical Methods of Data Analysis

Statistical calculations were entered into the database and automated using Excel (Microsoft Office Excel, version 2017, Microsoft Corp., USA) and SPSS (IBM SPSS Statistics, version 20.0, IBM Corp., USA) software. Statistical calculations included the following parameters: patients' age; pre- and postoperative visual acuity and IOP; duration of silicone oil tamponade; timing of silicone oil emulsification; and thickness of the macular ganglion cell layer.

The following types of variables were used: nominal (categorical) and quantitative. For each quantitative parameter, the mean and standard deviation (mean, standard deviation, M±SD) were calculated. To reject the null hypothesis, the significance threshold (p) was set at 0.05, which is considered adequate in biomedical research. Cases where the p-value was less than 0.01 were designated as $p < 0.01$.

When the distribution of data based on test results corresponded to normal (Gaussian) distribution parameters, the Student's t-test was used for continuous quantitative variables when comparing results between independent groups; however, when the data distribution did not correspond to normality based on test results or when large differences existed between variances, the Mann-Whitney U test (Wilcoxon rank-sum test) was used [13].

Pearson's chi-square ($\chi 2$) test was used to compare categorical (nominal) and ordinal variables. For small sample sizes, accuracy correction (Fisher's exact test) was applied [14].

A one-way ANOVA test was used to determine the difference in parametric means between two or more groups. In cases where significant differences were detected between groups, post-hoc tests Scheffe, Tukey, and Bonferroni) were used to perform pairwise comparisons between different groups [15, 16].

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To measure the strength of the association between two characteristics, the odds ratio was calculated.

Approval of the Study. The main provisions of the dissertation were presented at the 15th International Euretina Congress held in France in 2015; at the 53rd Congress of the Turkish Ophthalmological Association (TOD) in Turkiye in 2019; at the 23rd Euretina Congress in the Netherlands in 2023; at the annual conferences of Azerbaijani Retinologists in 2019, 2020, and 2023; at the IV Congress of Azerbaijani Glaucomatologists in 2023; and at the "Current Issues in Ophthalmology" Conference dedicated to the 99th anniversary of Academician Zarifa Aliyeva in 2022. The research work passed initial discussion at the Scientific Council of the National Ophthalmology Centre named after Academician Zarifa Aliyeva on November 26, 2025, and discussion at the Scientific Seminar on June 19, 2026, and was recommended for the main defense.

Institution where the Dissertation Work was conducted:

The study was conducted in the Department of Vitreoretinal Surgery and the Department of Ocular Complications of Diabetes Mellitus at the National Ophthalmology Centre named after Academician Zarifa Aliyeva.

Publication of the Main Results of the Dissertation: On the topic of the dissertation, 16 scientific works have been published, including 12 articles and 4 thesis. Of these, 10 were published in Azerbaijan and 6 abroad.

Volume and Structure of the Dissertation: The dissertation is written on 163 pages of typed text (202,682 characters) and is structured as follows: introduction – 12,117 characters; literature review – 57,339 characters; Chapter II – "Materials and Methods" – 31,694 characters; results of personal research – Chapter III – 30,545 characters; Chapter IV – 10,451 characters; Chapter V – 22,644 characters; discussion – 32,667 characters; conclusions – 2,673

characters; practical recommendations – 1,371 characters; and a bibliography consisting of 204 sources. The dissertation contains 26 tables, 36 figures, and diagrams.

MATERIALS AND METHODS OF THE STUDY

This work is a clinical study. The study used data from pars plana vitrectomy operations performed on 443 eyes of 427 patients observed in the departments of "Eye Complications of Diabetes Mellitus" and "Vitreoretinal Surgery of the Eye" at the National Centre of Ophthalmology named after Academician Zarifa Aliyeva between 2011 and 2023. Depending on the tamponade method, the patients were divided into two groups. The first – the main group – consisted of patients with silicone oil tamponade: 195 patients (199 eyes), of whom 36 eyes were operated on due to rhegmatogenous retinal detachment (18.09%) and 163 eyes due to tractional detachment resulting from proliferative diabetic retinopathy (PDR) (81.91%). The second – the control group – consisted of 244 eyes of 237 patients operated on with gas tamponade due to rhegmatogenous retinal detachment – 56 eyes (22.95%) and tractional detachment – 188 eyes (77.05%).

The mean age of the patients in the main group was 63.7 ± 9.1 years (range, 28–81 years). The majority of patients – 154 individuals (78.97%) – were aged 51 to 70 years, while a smaller number – 5 patients (2.56%) – were under 30 years of age. There were 121 female patients (62.1%) and 74 male patients (37.9%). Preoperative visual acuity averaged 0.064 ± 0.017 (ranging from light perception with accurate light projection to 0.6). The majority of patients in the main group – 147 eyes (73.87%) –received low-viscosity silicone oil (1000 centistokes), while 51 eyes (25.63%) received high-viscosity silicone oil (5000 centistokes).

The mean age of patients in the control group was 63.49 ± 9.84 years (range 29–85 years). The majority – 170 patients (71.7%), similar to the silicone endotamponade group – were aged 51 to 70 years, while a minority – 3 patients (1.22%) – were under 30 years old. Of the patients, 132 (55.7%) were female and 105 (44.3%) were male.

Patients underwent standard ophthalmic examinations, including visual acuity testing, biomicroscopy of the anterior segment, non-contact tonometry (Non-Contact Tonometer, Tomey, USA), and fundus biomicroscopy with a 90 D lens, as well as specialised examination using optical coherence tomography (Cirrus HD-OCT, Carl Zeiss Meditech, Germany).

Persistent elevation of intraocular pressure was defined as an increase of IOP above 23 mm Hg for 6 weeks or an increase above 30 mm Hg within 1 week.

OCT of the retina was performed to assess the condition of the macula – its thickness, presence of cystoid edema, epiretinal membrane, and macular detachment, as well as the thickness of its ganglion cell layer – in patients with both proliferative diabetic retinopathy and rhegmatogenous retinal detachments, as well as transparent light-transmitting media of the eye. Taking into account the specific features of retinal pathology, this examination was not performed in all patients. Due to reasons such as high macular detachment, vitreous hemorrhage and opacity, cataract, etc., pre-operative OCT was not feasible. OCT was performed pre-operatively in 56 cases in the main group and in 62 eyes in the control group. In addition, spectral OCT was performed post-operatively to detect emulsified silicone oil droplets in the anterior and posterior segments of the eye. Cirrus HD-OCT 400 (Carl Zeiss Meditec, USA) was used to evaluate macular structure and thickness. For the initial assessment of structural pathologies in the macular region, the “HD 5 line Raster” and the “Macular Cube 512x128” scan protocol with 3D visualization capabilities were used. To assess the thickness of the retinal ganglion cell layer, the “Macular Cube 512x128” scan protocol was selected,

utilizing the “Ganglion Cell OU Analysis” algorithm. Patients in the main group were examined one day before surgery and 1, 3, 6, 9, and 12 months after surgery. Patients in the control group were examined before surgery and 2, 3, 6, 9, and 12 months after surgery due to the specifics of perfluoropropane gas and its absorption period of 55–65 days. To evaluate the anterior segment of the eye, the “Anterior Segment” scan protocol was used, through which the iris and anterior chamber angle were visualized for the early detection of silicone oil droplets.

Results of the Study

In the main group (Group I), the final anatomical effect, complete retinal reattachment, was achieved in 178 eyes (89.5%) after one operation, in 5 eyes (2.5%) after two operations, and in 16 eyes (8.0%) after three operations (Figure 1).

In the control group, the final effect was achieved with one operation in 197 cases (80.7%), two operations in 45 cases (18.5%), and three operations in 2 cases (0.8%). Recurrences of retinal detachment developed more frequently in the group undergoing tamponade of the vitreous cavity with expanding gases; however, no significant differences were detected between the groups ($\chi 2 = 0.775$, $p = 0.38$; Fisher's exact value – 0.524, $p > 0,05$.

In the group of patients with silicone oil tamponade, the mean preoperative visual acuity on the decimal scale was 0.064 ± 0.017 (minimum – light perception with accurate projection, maximum – 0.6), and postoperatively it was 0.12 ± 0.02 (minimum – 0, maximum – 0.8). Visual acuity increased significantly ($p < 0.01$). Overall, visual acuity increased in 127 patients (63.8%) and decreased in 18 patients (9.0%). In the remaining patients, visual acuity remained unchanged – 54 eyes (27.1%).

In patients tamponaded with a gas-air mixture (Group II), the mean preoperative visual acuity on the decimal scale was 0.08 ± 0.009 (minimum – light perception with accurate projection, maximum – 0.7), and postoperatively – 0.24 ± 0.014 (minimum – 0, maximum –

1.0). When evaluating visual acuity before and after surgery, a statistically significant increase was observed ($p < 0.01$). Final visual acuity increased in 189 patients (77.5%), decreased in 24 (9.84%), and remained unchanged in 32 patients (13.11%) (Table 1).

Table 1.

Comparison of visual acuity in the main and control groups

Visual Acuity	Main Group	Control Group
Increased	127(63.8%)	187 (76.64%)
Unchanged	54 (27.1%)	32 (13.11%)
Decreased	18 (9.04%)	24 (9.84%)

Before surgery, the mean IOP in patients of the main group was 17.61 ± 0.7 mmHg (range, 3.0-32.1 mmHg). In the control group, the preoperative intraocular pressure averaged 18.1 ± 4.9 mmHg. On the first postoperative day, an increase in IOP was observed in many patients in both the main and control groups (Table 2).

Table 2.

Number of eyes showing changes in IOP values on the first postoperative day

Indicator	Main group (number of eyes, percentage)	Control group (number of eyes, percentage)
IOP elevation	138 (77.5%)	160 (65.7%)
including by 6 mmHg or more	39 (21.9%)	57 (23.36%)
IOP reduction	40 (22.5%)	77 (31.56%)
including by 6 mmHg or more	10 (5.6%)	42 (17.21%)

Mean IOP values in the study and control groups over the three-year postoperative period are presented in Figure 2. As shown in the graph, the mean IOP in patients of the study group increased during the early postoperative period. This elevation in mean IOP values is attributed not only to the effect of the tamponade agent (its excess or migration into the anterior chamber), but also to the postoperative inflammatory response and the topical administration of corticosteroid preparations. Subsequently, mean IOP slightly decreased in both groups and rose again in the study group 5 months postoperatively. By this stage, organic changes had already occurred in the anterior chamber angle under the influence of emulsified silicone oil. Overall, during silicone oil tamponade, mean intraocular pressure increased with longer duration of tamponade ($r = 0.73$). In the control group, peak mean IOP values at various postoperative timepoints were observed after 5 (21.7 ± 3.9 mmHg), 7 (20.6 ± 6.8 mmHg), and 24 (21.2 ± 6.3 mmHg) months. The highest individual IOP values were recorded during the first postoperative week and after 1 month.

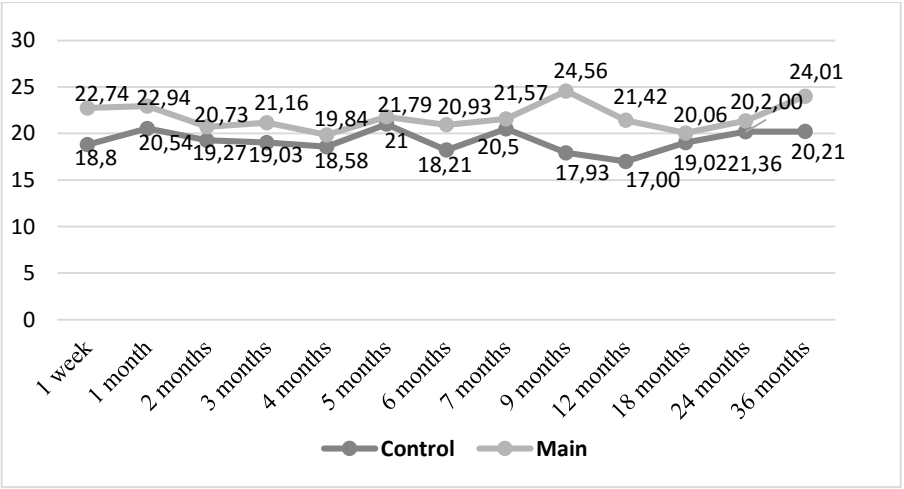


Figure 1. Mean IOP values in the main and control groups at various times in the postoperative period

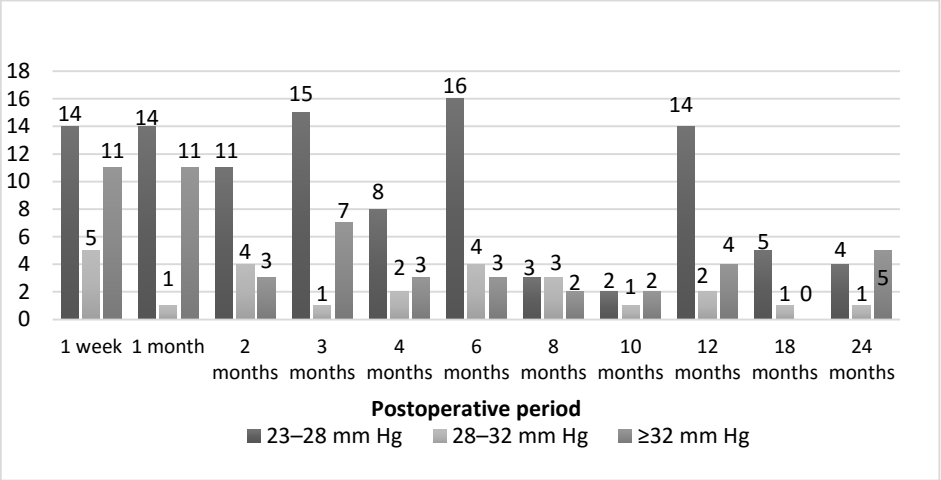


Figure 2. Number of eyes with elevated IOP in the main group at various time points in the postoperative period

Figures 2 and 3 present data on the number of patients with elevated IOP at corresponding time points in the main and control groups. As seen from the figures, during the first month after surgery, IOP increased in many patients in both the main and control groups. This is because the pathogenesis of IOP elevation in the first postoperative month is identical regardless of the tamponade method. This is related to both an excess of the tamponading agent, the postoperative inflammatory reaction, and the use of local steroids. However, at later postoperative stages, the number of patients with high IOP decreases in the control group, whereas in the main group it increases again, primarily after 6 months. In the main group, after 12 months, IOP of 23-28 mmHg was observed in 23 eyes (11.56%), while IOP exceeding 32 mmHg was observed in 8 eyes (4.02%). After 24 months, IOP of 23–32 mmHg was observed in 15 eyes (7.54%), and IOP exceeding 32 mmHg was observed in 10 eyes (5.03%). In the control group, after 12 months of follow-up, IOP of 23–28 mmHg was

observed in 10 eyes (4.09%) of the patients, while IOP exceeding 32 mmHg was observed in only 3 eyes (1.3%). After 24 months, IOP of 23–28 mmHg was observed in 4 eyes (1.64%), whereas IOP exceeding 30 mmHg was not detected (Fig. 3).

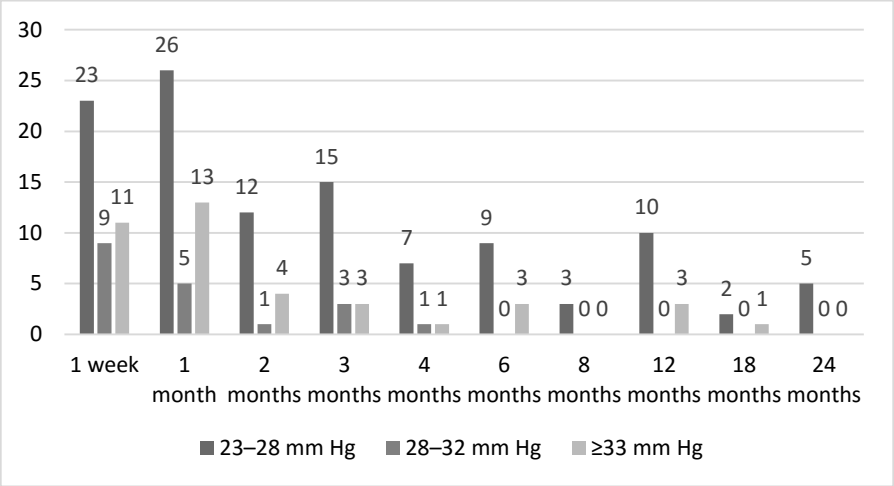


Figure 3. Number of eyes with elevated IOP in the control group at various time points in the postoperative period

During the 3-year follow-up period, transient IOP elevation was observed in 56 eyes (28.14%) in the main group, of which secondary glaucoma developed in 50 eyes (25.13%). In contrast, in the control group, persistent IOP elevation was observed in only 20 patients (8.2%) during the same period. This condition was mainly observed in the early stages of the postoperative period and was resolved with the use of combined hypotensive medications (brinzolamide and timolol maleate 0.5%).

In the study, the thickness of the retinal ganglion cell layer, determined by spectral-domain optical coherence tomography (SD-OCT), was analysed in both the main and control groups. This analysis

was performed to assess the effect of the type of tamponade on final visual acuity. In the main group, the mean preoperative thickness of the retinal ganglion cell layer was 47.26 ± 11.32 μm, compared with 46.25 ± 36.16 μm in the control group. In the preoperative period, the lower values were associated with the characteristics of the retinal pathology, namely oedema or macular detachment, as well as the presence of epiretinal membranes. The main parameters of macular ganglion cell layer thickness in the main and control groups are presented in the graph (Fig. 4).

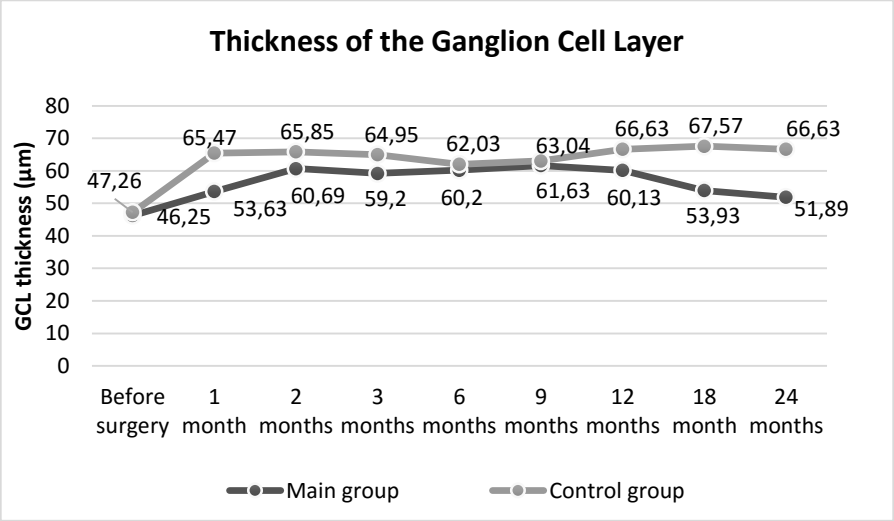


Figure 4. Mean values of the retinal ganglion cell layer thickness in the macular area of patients in the main and control groups at various times in the postoperative period

No statistically significant differences in ganglion cell layer thickness were observed between the main and control groups during the first 12 months after vitrectomy ($p>0.05$). However, after 12 months, a statistically significant thinning of the macular ganglion cell layer was observed in the main group, whereas thickening was detected in the control group. After 18 months, a significant difference

in this parameter was observed between the main and control groups ($p < 0.01$).

In addition, Pearson correlation analysis was performed to assess the dependence of visual acuity parameters on the thickness of the retinal ganglion cell layer in patients from both groups. The correlation coefficient between the retinal ganglion cell layer thickness and final visual acuity was 0.84 ($p<0.01$) in the silicone oil tamponade group and 0.71 ($p<0.01$) in the gas tamponade group. The analysis revealed a statistically significant positive correlation, meaning that as the thickness of the retinal ganglion cell layer increased, an improvement in patients' visual acuity was also observed.

The study also investigated the risk of developing secondary glaucoma resulting from silicone oil endotamponade. The findings revealed that the main risk factors for secondary glaucoma development following silicone tamponade include the viscosity of the silicone oil, the duration of silicone tamponade, and the severity of the proliferative process at the time of vitrectomy.

One of the main factors causing IOP elevation in patients with silicone tamponade, as well as the development of secondary glaucoma in the postoperative period, is the emulsification of silicone oil. In our study, emulsified silicone oil was detected in 64 of 199 cases (32.7%). On average, emulsification was detected after 5.9±4.2 months (ranging from 1 month to 18 months). Emulsified silicone is first detected in the posterior pole in the area of epiretinal membranes. This is likely due to the fact that when numerous proliferation factors (protein agents) mix with silicone oil, the interfacial tension of its droplets decreases, leading to emulsification. OCT revealed the presence of emulsified silicone oil in the anterior chamber angle region, in the lacunae of the iris, and beneath the epiretinal membrane at the optic nerve head. In our study, silicone oil with a viscosity of 5000 centistokes was injected in 30 patients. In the remaining 169 patients, silicone oil with a viscosity of 1000 centistokes was used.

Emulsification was detected in 61 of 169 eyes (36.09%) with 1000 cSt silicone oil tamponade, and in 3 of 30 eyes (10%) with 5000 cSt silicone oil tamponade. Thus, among the 64 eyes with detected silicone oil emulsification, 1000 cSt silicone oil tamponade was used in 95.31%, and 5000 cSt silicone oil tamponade in only 4.69%. The odds ratio for silicone oil emulsification was 5.08 times lower with high-viscosity silicone oil compared to low-viscosity silicone oil (OR = 5.08; 95%CI: 1.48–17.45; $p<0.01$). Persistent IOP elevation occurred in 52 of 169 eyes (30.77%) tamponaded with low-viscosity silicone oil, and in 4 of 13 eyes (13.33%) with high-viscosity silicone oil. The probability (odds) of IOP elevation was 4.03 times higher during tamponade with low-viscosity silicone oil ($p<0.05$).

Silicone oil emulsification occurred in 93.3% (61 eyes) with 1000 ct viscosity and in only 3 eyes (4.7%) with 5000 centistokes silicone oil tamponade. Thus, in our study, emulsification of high-viscosity silicone oil occurred significantly less frequently ($\chi 2= 7.952$, $p < 0.01$).

As can be seen from Figure 5, persistent IOP elevation was noted in 4 of 30 eyes (13.33%) operated on for rhegmatogenous retinal detachment, and in 52 of 169 eyes (30.77%) with tractional retinal detachment. The frequency of persistent IOP elevation in eyes with TRD was 2.31 times higher than in eyes with RRD. According to Fisher's exact test, the difference between the groups did not reach statistical significance ($p=0.076$). Thus, no statistically significant difference in the frequency of persistent IOP elevation was found between eyes with RRD and TRD.

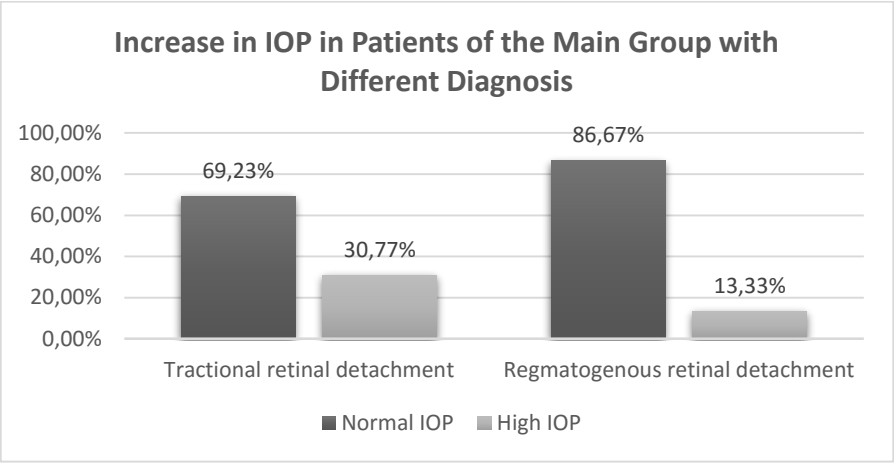


Figure 5. Proportion of patients with high IOP in eyes with tractional and rhegmatogenous retinal detachment

This trend is associated with a more severe proliferative process in proliferative diabetic retinopathy (PDR) and tractional retinal detachment. In patients with pronounced proliferative vitreoretinopathy, multi-membrane diabetic retinopathy, or vitreous hemorrhage, emulsification occurs more rapidly.

Furthermore, one of the main factors causing IOP elevation during silicone tamponade is its duration of retention in the eye. Persistent IOP elevation was noted in 14.89% of cases when silicone oil was removed within up to 3 months, in 22,67% of cases after 4–6 months, in 34,88% of cases after 7–12 months, and in 50% of cases when removed between 13 and 36 months (Table 3). The frequency of ocular hypertension was significantly higher in patients with silicone oil tamponade exceeding 12 months compared to those with tamponade up to 3 months ($\chi^2 = 14,19$; df=3; $p < 0.01$). The probability of IOP elevation in patients with a tamponade duration of more than 12 months was 5,71 times higher compared to those with tamponade up to 3 months (OR = 5,71; 95% CI: 2,01–16,29; $p < 0.01$).

Table 3.

Duration of silicone oil tamponade and the proportion of patients with high IOP

Duration of silicone oil tamponade	Total number of patients	Number of patients with high IOP	Proportion of patients with high IOP
> 3 months	47	7	14.89 %
4-6 months	75	17	22,67%
7-12 months	43	15	34,88%
>12 months	34	15	50%

Thus, the main risk factors for the development of secondary glaucoma during silicone endotamponade can include the following: the duration of silicone endotamponade, the viscosity of the silicone oil, and the underlying diagnosis leading to vitrectomy.

The main criteria for silicone oil removal are as follows: 1) complete retinal attachment and resorption of preretinal hemorrhages; 2) development of a tractional proliferative epiretinal membrane in the central zone of the retina affecting visual acuity; 3) development of cataract negatively affecting visual acuity and the ability to visualize the fundus; 4) sustained elevation of IOP above 25 mm Hg for more than 4 weeks despite the use of antiglaucoma medications; 5) presence of emulsified silicone in the anterior chamber.

The mean duration of silicone tamponade was 8.46 ±1.46 months. During the entire observation period, silicone oil was removed in 186 patients (93.47%), and silicone oil was exchanged in 13 patients (6.53%). Silicone oil was exchanged within 3.57 ± 2.6 months (range, 1–11 months).

In most cases, silicone oil was removed within up to 6 months (61.81% – in 123 eyes). In 80.9% of cases (161 eyes), silicone oil was removed within one year.

As noted above, transient IOP elevation was observed in 56 of 199 patients (28.14%) who underwent pars plana vitrectomy with silicone oil tamponade, and secondary glaucoma developed in 50 eyes (25.13%). In our study, IOP normalized in 18 eyes (36%) following the removal or exchange of silicone oil. In most cases, normalization of IOP was achieved medically.

In 11 eyes, surgical intervention became necessary due to the ineffectiveness of medical therapy. An Ahmed Glaucoma Valve (AGV) drainage device was implanted in these patients (Table 4). This surgery was performed on average 10.3±8.9 months after vitrectomy (observation period, 1–24 months).

Table 4.

Treatment of patients with secondary glaucoma resulting from silicone oil tamponade of the vitreous cavity

Treatment methods for glaucoma		Number of eyes	%
Medical treatment (44 patients)	Monotherapy Combination drugs	9 35	4.5 17.6
Surgical treatment	AGV implantation	11	5.5

The choice of this surgical approach is due to the following reasons: 1) Filtering surgeries are ineffective in eyes following vitrectomy. This ineffectiveness is associated both with scarring in the conjunctiva and the structures of the anterior chamber angle due to the effect of silicone oil, and with the blockage of the filtration ostium by silicone oil droplets. 2) Unlike other drainage devices, valved drainage

devices provide an immediate decrease in IOP postoperatively and prevent the development of complete optic nerve atrophy resulting from high IOP.

In our study, the mean intraocular pressure of patients prior to AGV implantation was 43.2 mm Hg. On the first day after surgery, it was 24.2 mm Hg ($p < 0.01$). Subsequent mean values of IOP are presented in Figure 6. Nevertheless, the success rate of the surgery was 81.82% within 12 months postoperatively.

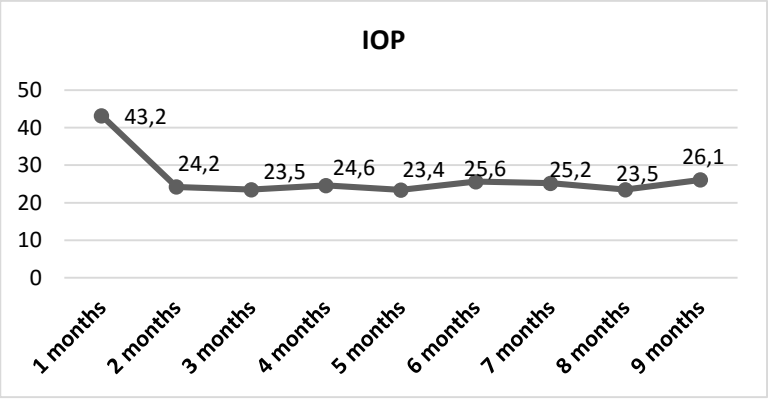


Figure 6. Mean intraocular pressure in patients with secondary glaucoma associated with silicone oil tamponade at various time points before and after Ahmed Glaucoma Valve implantation

The study also analyzed the results of the effect of retinectomy on IOP dynamics in the postoperative period. Two groups of patients with silicone oil tamponade of the vitreous cavity were compared. The first group included 16 eyes of 16 patients with PDR who underwent retinectomy, and the second group included 19 eyes of 17 patients with PDR who underwent vitrectomy without retinectomy. In all cases, retinectomy was performed to achieve the elimination of ischemic retina and complete retinal reattachment.

During the observation period, stable normal values of intraocular pressure were observed in patients who underwent retinectomy. In contrast, an increase in mean intraocular pressure values was observed at various time points in the postoperative period in patients without retinectomy (Table 5). Thus, a statistically significant difference in mean IOP values was detected between these two patient groups in the postoperative period ($p < 0.01$).

Table 5.

Mean intraocular pressure (IOP) values before and different period after vitrectomy groups of patients operated with and without retinectomy

Treatment duration	İOP in eyes after vitrectomy with retinectomy, mm Hg		İOP in eyes after vitrectomy without retinectomy, mm Hg	
	Mean value	Standart deviation	Mean value	Standart deviation
Before surgery	13,8	3,8	17,1	5,9
After surgery	14,0	4,8	23,3	5,5
1 month	14,4	5,7	33,1	12,7
2 month	12,3	3,2	15,1	5,5
3 month	15,2	3,6	23,9	2,1
4 month	15,0	3,0	14,7	5,6
5 month	13,9	2,0	16,8	4,0
6 month	13,9	2,0	22,0	1,0
10 month	14,6	3,1	24,2	15,2
12 month	14,8	4,8	24,2	15,2
18 month	17,3	6,1	21,6	2,6
24 month	16,6	4,0	26,2	9,5

The study demonstrates that in the postoperative period, retinectomy leads to a decrease in IOP in patients with proliferative

diabetic retinopathy compared to those who did not undergo retinectomy. It is hypothesized that, alongside directly reducing ischemia by eliminating chronic retinal detachment, retinectomy leads to a decrease in IOP by directly enhancing uveal outflow of aqueous humor through the retinal pigment epithelium.

RESULTS:

1. Transient IOP elevation was observed in 56 of 199 patients (28.14%) who underwent pars plana vitrectomy with silicone oil tamponade. Among these patients, a sustained IOP elevation was observed in 50 patients (25.13%) during a 3-year post-vitrectomy observation period, which led to the development of optic neuropathy. The mean duration of IOP elevation was 4.27 ± 1.16 months.
2. The development of secondary glaucoma during silicone oil endotamponade is influenced by the following risk factors: a) duration of silicone endotamponade: the probability of IOP elevation increases with longer tamponade duration (χ^2=14,19; df=3; p<0,01). The probability of IOP elevation in patients with a tamponade duration exceeding 12 months was 5,71 times higher compared to those with a tamponade duration of up to 3 months ($p < 0.01$). b) Viscosity of the silicone oil used: the odds ratio of IOP elevation when using low-viscosity silicone oil (1000 centistokes) is 6.57 times higher compared to high-viscosity silicone oil (5000 centistokes) ($p < 0.01$). c) Structural changes of eye fundus: compared to rhegmatogenous detachment, the risk of intraocular pressure elevation is 2.31 times higher in tractional retinal detachment.
3. The removal of silicone oil: a) complete retinal reattachment, resorption of preretinal hemorrhages; b) development of a proliferative epiretinal membrane causing traction in the central zone of the retina and affecting visual acuity; c) development of cataract affecting visual acuity and fundus examination; d) IOP exceeding 26 mm Hg for more than 4 weeks despite the use of antiglaucoma medications;

e) presence of emulsified silicone oil in the anterior chamber, is determined on an individual basis.

4. OCT examination revealed a significant decrease in the mean thickness of the ganglion cell layer of the retina in the silicone oil endotamponade group compared to the control group 12 months postoperatively ($p < 0.05$). The correlation coefficient between the retinal ganglion cell layer thickness and final visual acuity was 0.84 ($p < 0.01$) in the silicone tamponade group and 0.71 ($p < 0.01$) in the gas tamponade group.
5. Effective treatment was achieved with medical hypotensive therapy in 75% of patients with elevated IOP following silicone endotamponade. Eleven patients refractory to conservative treatment underwent surgical intervention via AGV implantation. The surgical success rate was 81.82% within observation period.

PRACTICAL RECOMMENDATIONS:

1. In cases where long-term tamponade of the vitreous cavity is required (proliferative vitreoretinopathy, rhegmatogenous retinal detachment with a giant retinal tear, chronic tractional retinal detachment), it is recommended to use higher-viscosity silicone oil (5000 centistokes).
2. OCT should be used for the early detection of emulsified silicone oil droplets during postoperative follow-up. Furthermore, OCT helps detect emulsification at an early stage on the iris surface and in the anterior chamber angle.
3. The active aspiration technique of silicone oil without a trocar-inserted silicone cannula ensures a more rapid removal of silicone oil. In our study, normalization of IOP occurred in only 36.4% of cases in patients with secondary ocular hypertension developing after the removal of silicone oil from the vitreous cavity.
4. In non-functional or low-functional eyes, performing peripheral retinectomy is recommended as a surgical treatment for sustained IOP elevation associated with silicone endotamponada.

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LIST OF ABBREVIATIONS:

İOP – İntraocular pressure
İOF – İntraocular fluid
OCT – Optical Coherent Tomography
PDR – Proliferative Diabetic Retinopathy
ERM – Epiretinal Membrane
OND – Optic Nerve Disc
AGV – Ahmed Glaucoma Valve
QCC– Ganglious Cell Complex
RNFL –Retinal Nerve Fiber Layer
RD – Retinal Detachment
TRD – Tractional Retinal Detachment
RRD – Regmatogenous Retinal Detachment
NVQ – Neovascular Glaucoma

The defense will be held on 11 december 2026 at 14:00 at the meeting of the Dissertation Council FD 1.03 of Supreme Attestation Comission under the President of the Republic of Azerbaijan operating at the National Ophthalmology Centre named after Academician Zarifa Aliyeva.

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Abstract was sent to the required addresses on 12 november 2026.

Signed for printing: 06.11.2026.
Paper format: 60x84 1/16.
Volume: 37033 characters
Number of hard copies: 20.