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Shallow anterior chamber depth: is this a contraindication, or are there options for phakic lens implantation?

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Background. *High myopia is a refractive error and a serious problem among teenagers. This condition can lead to significant vision impairment if left unaddressed, affecting their daily activities and overall quality of life.*

Purpose. *To estimate clinical results after phakic lens implantation in patients with high myopia and shallow anterior chamber depth during the 24-month postop period.*

Material and methods*. In this retrospective observational study, we aimed to analyze clinical results of 226 eyes in 131 patients who had undergone implantable collamer lens (ICL) implantation. Pre- and postoperative clinical parameters have been evaluated at 1 day, 1 week, 1, 3, 6, 12 and 24 months in the postoperative period.*

Results. *A total of 226 eyes of 131 patients had underwent ICL implantation in Republican Specialized Scientific and Practical Medical Center of Eye Microsurgery from January 2020 to December 2023. Initially, we separated all eyes into two groups. Group A that had anterior chamber depth (ACD) ≥ 2.8 mm and Group B that had an ACD < 2.8 mm. The mean pre-op ACD was 2.95±0.13 mm was 2.65±0.15 mm in Group A and B, respectively. The mean age of all patients was 25.68±4.3. The mean pre-op manifest spherical equivalent was -8.65±2.72 D, and the manifest cylinder was -2.43±0.53 D, respectively (p≤0.001), with postoperative refractive measures reduced to -0.5±0.12 D (p≤0.001). The mean IOP was 14.8±2.3 mmHg preoperatively. The mean IOP has changed to 15.23±1.86 mmHg during 24 months in the postoperative period.*

Conclusion*. Phakic IOL implantation is an alternative method for correcting high refractive errors. Even when the anterior chamber depth is below the required parameters, the surgeon can still implant ICL and achieve optimal postoperative results. However, in these cases, all patients must be thoroughly prepared for the planned surgery and should be monitored periodically for intraocular pressure and ICL vault measurements during the long-term postoperative period.*

Key words:

myopia, visual acuity, implantable collamer lens, phakic, corneal endothelium, intraocular pressure, anterior chamber

Introduction

Introduction. Refractive errors (myopia, hyperopia, or astigmatism) affect all age groups and are the most commonly reported ocular conditions globally. If left uncorrected, refractive errors can lead to social and economic consequences for both patients and their families [1].

According to the estimates of the World Health Organization 2022 (WHO), 285 million people are visually impaired, including 246 million having low vision and 39 million blind. Research studies have also revealed that the most common reason for a visit to an ophthalmologist or eye care professional is related to refractive errors [2].

Myopia and astigmatism are common eye disorders and are leading causes of visual impairment and treatable blindness in the general population. An axial lengthening and a positive image position in relation to the retina characterize myopia. It is often linked to changes in the structure of the retina and choroid. Accommodation cannot overcome the reduction in visual acuity (VA) that myopia causes. In addition, highly myopic eyes, that is, of -6 diopters (D) or more, may develop sight-threatening complications, leading to visual impairment at a young age [3].

These days, keratorefractive surgery, refractive lens extraction (RLE), and phakic intraocular lens (pIOL) implantation can fix refractive errors like high myopia and myopic astigmatism. We classify phakic IOLs into two categories: anterior chamber (AC pIOL) and posterior chamber (PC pIOL). Based on their attachment to the eye, there are two additional types of anterior chamber pIOLs: angle fixated and iris fixated. Surgeons commonly use them to treat high myopia because they can correct higher refractive errors than corneal refractive procedures [4, 5].

There are several benefits to using posterior chamber phakic IOLs to correct high myopia and astigmatism, including the ability to be reversed, to fully correct, to be

minimally invasive, to give accurate predictions, and to keep the eye's ability to accommodate [6].

Purpose. To estimate clinical results after phakic lens implantation in patients with high myopia and shallow anterior chamber depth during the 24-month postoperative period.

Material and methods

This research group is composed of patients with high myopia and myopic astigmatism who underwent implantation of spheric and toric implantable collamer lenses (VICM5 and VTICM5 models) from January 2020 to December 2023 at the Republican Specialized Scientific and Practical Medical Center of Eye Microsurgery, Tashkent, Uzbekistan. Totally, 226 eyes in 131 patients had been implanted with the above-mentioned models of phakic IOLs. Those patients in whom LASIK surgery was contraindicated because of a thin cornea and a range of myopia were higher than -6.0 diopters (D), and myopic astigmatism was more than -2.0 diopters. All patients had stable refractions within ±0.75 D for 1 year before surgery. However, the main goal of this study was to examine the patients who had high refractive errors and a lower anterior chamber depth before surgery, which was needed for the surgical indication section of ICL implantation. One of the indications for implantation was anterior chamber depth from the endothelium to the anterior surface of the crystalline, which should be at least 2.8 mm. This parameter plays a significant role in preventing postoperative complications such as cataract and secondary glaucoma in the postoperative period. Therefore, we aimed to compare two groups of patients who had undergone ICL implantation. Group A contained 202 eyes of 116 patients who had ACD measures of 2.8 mm or above. Group B contained 24 eyes of 15 patients whose ACD measures were lower than 2.8 mm. All required examinations were done preoperatively. Each patient was observed by specialized ophthalmic examination such as bio-ophthalmoscopy with dilated pupil by using a 90 D aspheric lens (Volk Inc. USA), A & B ultrasound scanning of the eye globe (UD-800 A/B scan, Tomey, Japan), non-contact tonopachymetry (CT-1P, Topcon, Japan), autorefkeratometry (KR-1, Topcon, Japan), keratotopography (ORBSCAN III, ZYWAVE3, Germany), and anterior and posterior segment OCT (Triton DRI Plus, Topcon, Japan). IOL power calculation was performed based on cycloplegic refraction, keratometry, axial length, anterior chamber depth (ACD), and lens thickness. Patients with peripheral retinal tears and lesions were treated by using a green laser coagulator (Novus Spectra, Lumenis, USA). Exclusion criteria included lens opacities, peripheral retinal detachments, history of uveitis, glaucoma, corneal pathology, etc. Informed and written consents were obtained in each case. Each patient received comprehensive information about the phakic IOL implantation procedure, aligning with the Helsinki Declaration. In all cases, intraocular pressure measurements and gonioscopy was done to ensure wide-open angles, best corrected visual acuity (BCVA), and uncorrected visual acuity (UCVA), which were recorded preoperatively and postoperatively. We measured the White-to-White (WTW) diameter using a digital biometric ruler and a digital caliper. We calculated the ICL power using the STAAR Surgical OCOS system (Online Calculation and Order System) at https://evo-ocos.staarag.ch/Live/. We used anterior segment OCT (Triton DRI Plus, Topcon, Japan) on each eye to measure the vault distance between the ICL and the front surface of the clear natural lens at one week, three months, six months, and twenty-four months after surgery.

Statistical analysis

We performed all statistical analyses using Microsoft Excel (2019 version, Microsoft Corporation, Redmond, WA, USA). All statistical analyses were performed using SPSS v25.0 (IBM Corporation, Armonk, New York, USA). A Student's t-test was used for statistical analysis to compare the preoperative and postoperative data in both groups. The safety index (defined as the ratio between postoperative BCVA and preoperative BCVA) and efficacy index (defined as the ratio between postoperative UCVA and preoperative BCVA) were calculated based on Snellen decimal visual acuity values. The results were expressed as mean ± standard deviation (SD), and a value of $p \leq 0.05$ was considered statistically significant (CI 95%).

Ethical consideration

Ethical approval was obtained from the Research Ethics Committee of Center for the Development of Professional Qualifications of Medical Workers in Tashkent, Uzbekistan. This study was adhered to the Declaration of Helsinki and was registered as scientific research work with the institutional scientific board. Each patient signed the informed written consent before surgical intervention, and got agreement from accompanied personal by clinical staff.

Results

Patients who were recruited in this study had refractive errors greater than -6.25 D, indicating high myopia. One ophthalmic surgeon performed phakic IOL implantation in all eyes over a period of four years. Preoperative demographic data are listed in Table 1. All eyes had successful surgery, and there were few intraoperative and early postoperative complications encountered.

All patients who underwent pIOL implantation surgery were observed postoperatively at 1 day, 1 week, 1, 3, 6, 12 and 24 months. UCVA, BCVA, intraocular pressure, endothelial cell density and central vault volume (distance between the pIOL and the front surface of the crystalline lens) were checked in the postoperative period.

The mean changes in manifest spherical and cylinder refractions from 1 day to 24 months in both groups are demonstrated in Figures 1 and 2. There were no significant changes between the two groups and postoperative refractive results during the 24-month follow-up period.

We found a statistically significant difference between preoperative UCVA and BCVA in both groups with a 24-month postoperative period ($p<0.001$, Student's paired t-test). (Fig. 3, Fig. 4).

Table 1. Preoperative patient demographic data and pIOL characteristics (n = 226 eyes)

Characteristic		Mean ± SD (range)		Student t-test p <
		Group A (202 eyes)	Group B (24 eyes)	
Age (years)		25.52 ± 4.2 (20 to 36)	26.3 ± 5.4 (21 to 38)	-
Manifest spherical equivalent (D)		- 8.45 ± 2.67 (- 6.25 to - 14.75)	- 7.25± 2.45 (- 6.25 to - 12.50)	0.037
Manifest cylinder equivalent (D)		- 2.45 ± 0.75 (- 2.12 to - 3.75)	- 2.24 ± 0.5 (- 1.75 to - 2.75)	0.001
UCVA by Snellen		0.04 ± 0.02 (0.02 to 0.06)	0.05 ± 0.03 (0.02 to 0.10)	0.001
BCVA by Snellen		0.25 ± 0.12 (0.10 to 0.7)	0.3 ± 0.16 (0.10 to 0.75)	-
Horizontal white-to-white distance (mm)		11.56 ± 0.35 (10.8 to 12.3)	11.34 ± 0.25 (10.4 to 12.5)	0.013
Anterior chamber depth (mm)		2.95 ± 0.13 (2.80 to 3.35)	2.65 ± 0.15 (2.52 to 2.75)	-
Axial length (mm)		25.7 ± 1.5 (23.85 to 28.1)	25.3 ± 1.8 (23,7 to 27.2)	0.024
Central corneal thickness (μm)		489.1 ± 23.2 (445 to 526)	492.3 ± 25.1 (456 to 532)	-
Keratometric readings (D)	K1	43.1 ± 2.16 (39.00 to 45.25)	42.5 ± 1.7 (39.50 to 46.25)	0.042
	K2	43.5 ± 2.3 (39.75 to 47.50)	43.25 ± 1.9 (40.20 to 47.50)	0.001
Intraocular pressure (mmHg)		14.7 ± 2.5 (12 to 20)	15.1 ± 2.2 (13 to 21)	0.032
Endothelial cells density (cells/mm^2)		2895 ± 127 (2631 to 3012)	2876 ± 132 (2598 to 3043)	-

Note. UCVA, uncorrected visual acuity. BCVA, best corrected visual acuity. SD, standard deviation. Student`s t-test, P = probability, p ≤ 0.05, CI 95%. (–) has not statistically significant value p > 0.05

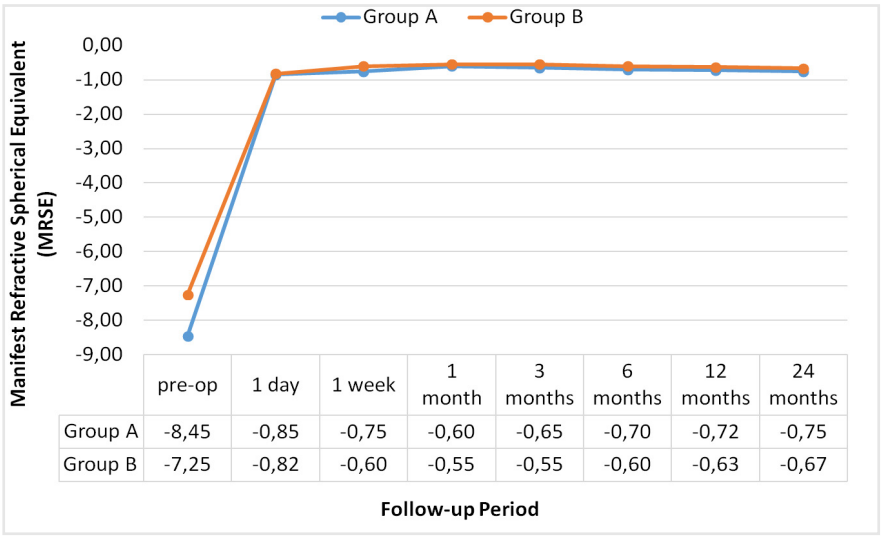

Figure 1. Changes in mean spherical equivalent during the 24-month postoperative

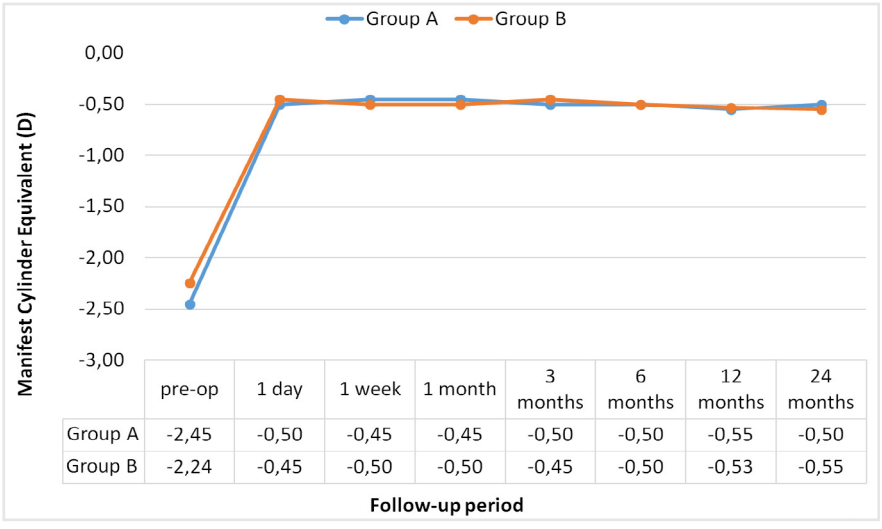

Figure 2. Changes in mean cylinder equivalent during the 24-month postoperative

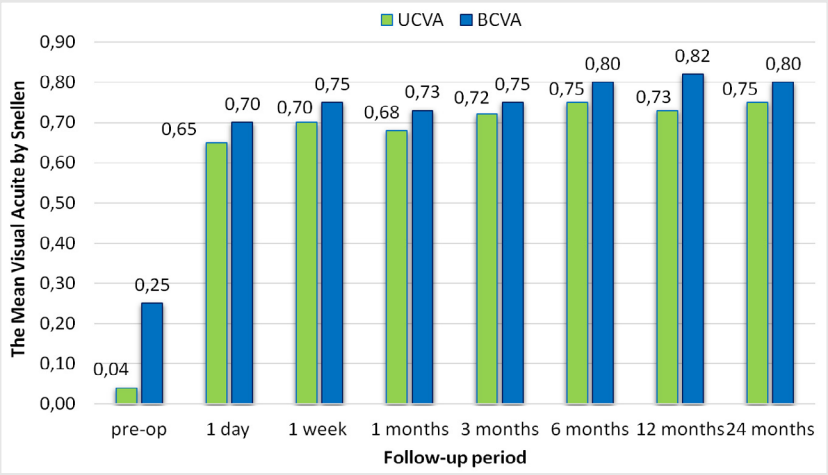

Figure 3. Changes of UCVA and BCVA in Group A during the 24-month postoperative

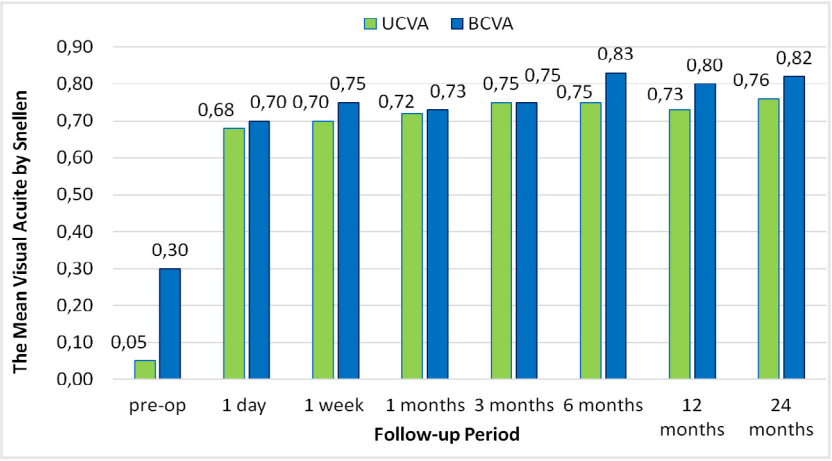

Figure 4. Changes of UCVA and BCVA in Group B during the 24-month postoperative

The remained manifest spherical equivalent (MSE) correction in one day, 1 week, 1, 3, 6, 12, and 24 months after surgery: 95% of eyes were within ±0.5 D, respectively, of the attempted SE correction. Before surgery, the manifest SE in Groups A and B was -8.45±2.67 D and -7.25±2.45 D, but after surgery, it was -0.5±0.75 D ($p<0.001$, Student's paired t-test). After PIOL implantation, patients with normal and shallowACD should evaluate two of the most important parameters: IOP and vault. As mentioned above, the central port facilitates aqueous flow, which helps keep IOP at appropriate levels. In this study, IOP and vault parameters were carefully analyzed depending on ACD.

In Group A, the mean preoperative IOP was 14.70±2.5 mmHg and suddenly increased up to 16.48 mmHg on the first day postoperatively. This measure significantly decreased to 14.98 mmHg on the 3-month follow-up period and remained unchanged at 14.95 mmHg on the 24-month follow-up period. In Group B, the mean preoperative IOP was 15.10±2.2 mmHg and increased to 16.95 mmHg at 1day of the postoperative period. It significantly decreased to 15.63 mmHg and remained stable at 15.89 mmHg in the 24-month postoperative follow-up period. Respectively. These changes are not statistically significant ($p<0.524$). (Fig. 5).

Additionally, we found high IOP in 9 (4.45%) eyes out of 202 eyes in Group A. On the first day of the postoperative period, IOP increased to 33.4 mmHg. The same situation was in Group B. However, of the 24 eyes in this group, seven (29.1%) showed high intraocular pressure. The mean elevated IOP was 29.6±3.1 mmHg in the first-day postoperative period. In both groups, we immediately prescribed Sol. Timolol 0.5% - 5 ml, eye drops twice a day for one week. IOP slowly decreased to 16.3 mmHg during the first week, respectively. It is evident in the previously mentioned data. In Group B, there was more risk of increasing IOP in the early postoperative period than in Group A.

One of the main parameters is vault (distance between the anterior surface of the natural lens and the implanted posterior chamber intraocular lens). In Group A, the mean vault was 327.5±112 µm on the first day of the postoperative period. This value slightly increased to 495.65±94 µm at 6 months and decreased to 439.24±105 µm at 24 months of the postoperative follow-up period ($p<0.001$, Student's paired t-test). We determined the minimal mean vault of 214 µm and the maximal mean vault of 657 µm during the entire follow-up period. In Group B, the mean vault on the first day after surgery was 214.7±68 µm, and it increased to 327.3±85 µm at 6 months of the follow-up pe-

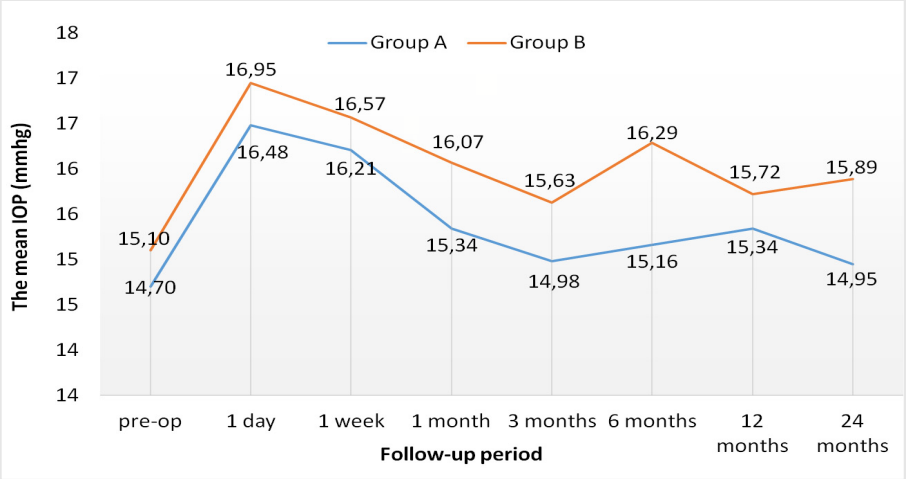

Figure 5. Changes in IOP during the 24-month postoperative

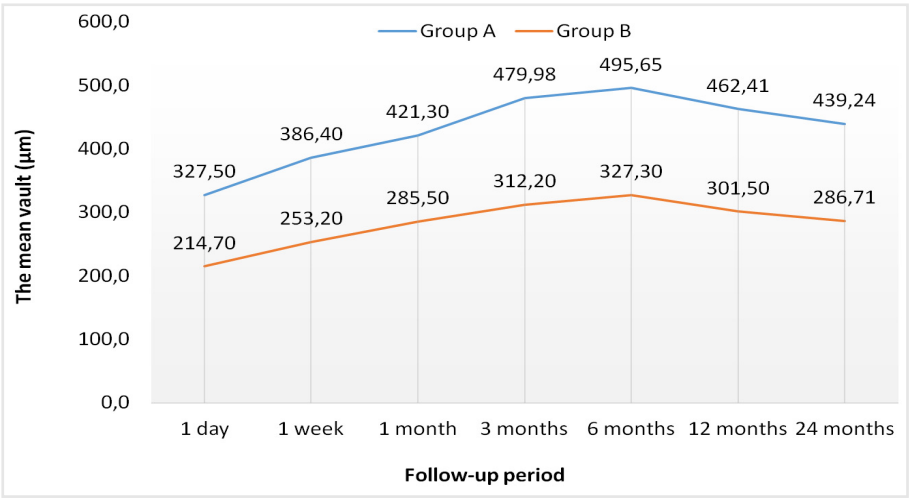

Figure 6. Changes in vault during the 24-month postoperative

riod. Then this value significantly decreased to 286.71±89 µm at 24 months of the postoperative follow-up period ($p<0.001$, Student's paired t-test). In Group B, the minimal and maximal mean vault was 118 µm and 435 µm, respectively, during the entire follow-up period. (Fig. 6).

After phakic IOL implantation, each eye would lose its endothelial cells during the irrigation aspiration procedure. It will decrease the number of cells. This parameter significantly influences the overall condition of the eye. The value of lost cells depends on the duration of the irrigation and aspiration procedure and the volume of ACD [10, 12].

In Group A, as well as eyes with normal ACD, showed a decrease in the pre-op ECD value from 2895±127 cells/mm² to 2725±113 cells/mm² at 6 months of the follow-up period. The mean ECD loss was 5.87% in the early follow-up postoperative period. The mean pre-op ECD value changed from 2895±127 cells/mm² to 2657±95 cells/mm² at 24 months of the follow-up period. The mean ECD loss for these periods was 8.2% in the long-term follow-up postoperative period.

In Group B, opposite to Group A, ECD value decreased from 2876±132 cells/mm² preoperatively to 2684±104 cells/mm² at 6 months of the follow-up period. The mean ECD loss was 6.67% in the early follow-up period. Comparing this preoperative ECD value to the mean ECD value in the 24-month follow-up period, we found significant changes in cell loss ($p<0.001$, Student's paired t-test). The mean ECD loss for this period was 9.18%. These data are presented in Figure 7.

Complications

No serious intraoperative complications were observed while implanting phakic IOLs in patients with high refractive errors. However, phakic IOLs were repositioned in only 10 (4.95%) of 202 eyes in Group A during the follow-up period. In any case, re-implantation was not needed. We matched the increase of IOP totally in 16 (7.92%) eyes during the 24-month follow-up period. Figure 8 displays only 3 eyes from Group A. One day after surgery, only 9 eyes had elevated IOP, and only 4 eyes exhibited high IOP one week after surgery. Subsequently, this parameter decreased to 16.3 mmHg during the follow-up period. High IOP persisted in only two eyes in the first month of the postoperative follow-up period. These cases were more likely linked to increased intracranial pressure. Following a neurologist's prescription, IOP quickly returned to normal limits by 3 months of the postoperative follow-up period. Only 1 of 4 (1.98%) eyes showed pigment dispersion on the first day and at 1 week of follow-up. This is not a dangerous complication in eyes with phakic IOL implants. Therefore, IOP should be monitored to be aware of

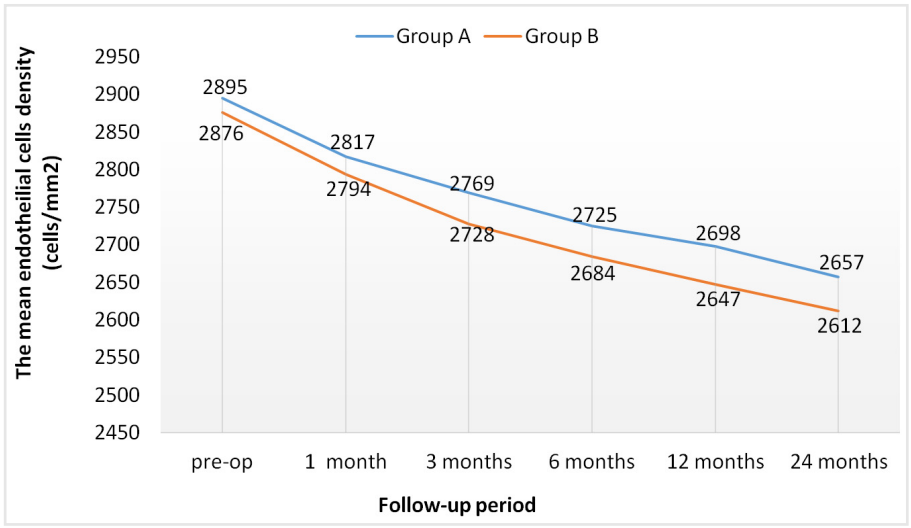

Figure 7. ECD changes during the 24-month postoperative

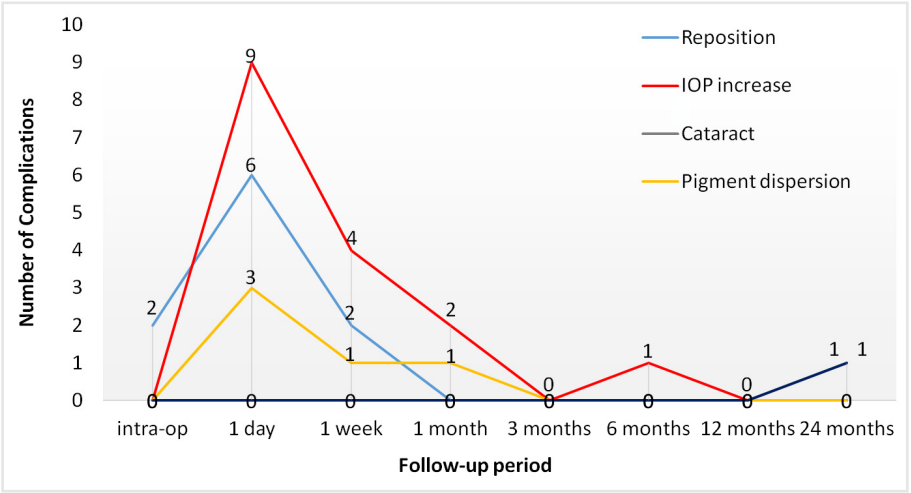

Figure 8. Acquired Complications in Group A during the 24-month postoperative

any pigment glaucoma progression. No other serious complications were observed during the early postoperative follow-up period. Only 1 eye (0.49%) experienced retinal detachment during the 24-month follow-up postoperative period. We immediately referred this patient to a vitreoretinal surgeon. (Fig. 8).

Only 1 of the 3 phakic IOLs in Group B eyes underwent repositioning during the intraoperative period. Repositioning of the remaining two eyes was performed on the first day of the postoperative period. The main increased parameter was IOP, which was not maintained from the first day until the 24-month of the follow-up period. On the first day of the postoperative period, IOP suddenly increased in 7 (29.1%) eyes and immediately decreased in five eyes during the first week of the follow-up period.

IOP continued to decrease until the first month of the postoperative period. Only 1 eye maintained an increased IOP at 1, 12, and 24 months of the follow-up period. Only 1 eye showed signs of pigment dispersion throughout the follow-up postoperative period. During the follow-up period, both groups neither developed secondary glaucoma nor experienced any other serious complications. (Fig.9).

Discussion

In this study, we report the outcomes of phakic IOL implantation in normal and shallow ACD eyes with a 24-month postoperative follow-up period. As noted in the literature, ACD from the endothelium to the anterior surface of the crystal should be at least 2.8 mm to perform this type of surgery [4, 6]. Despite the ACD criteria and the relatively small sample size of data, we demonstrate that ICL implantation is a safe, effective, and predictable method for the correcting high refractive errors. We could analyze the main measures, such as intraocular pressure, endothelial cell density, and vault after ICL implantation in both of the phakic IOL implanted patients` groups.

As mentioned above, IOP changed significantly from the preoperative to the postoperative follow-up period. Most importantly, it slightly increased at 1 day and 1 week after surgery and decreased during the next follow-up periods after prescribing hypotensive eye drops. It depended on the remaining adhesive viscoelastic device in the anterior chamber. According to Packer M., a mild and transient increase of IOP during the first month was noted in the study of Higueras-Esteban et al. [7].

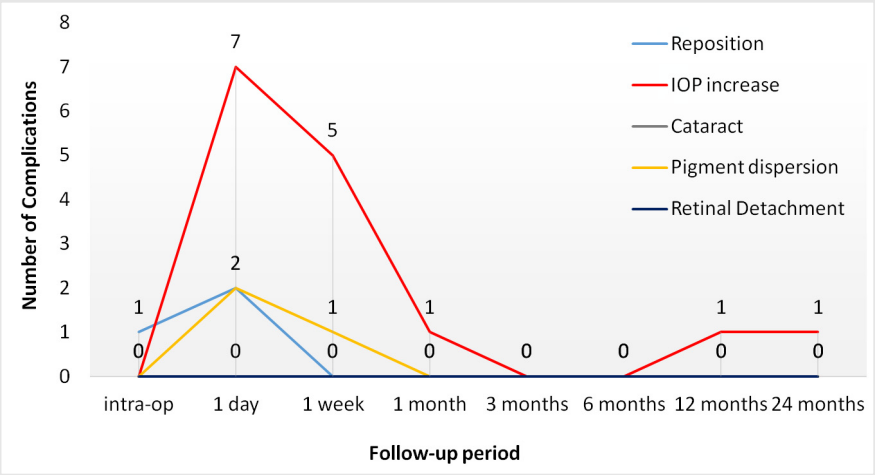

Figure 9. Acquired Complications in Group B during the 24-month postoperative

Vault value is the most important after implantation and should be monitored during the entire postoperative period. The literature recommends a vault between 250 and 750 µm. Normal mean vault should be 450±50 µm [8, 9, 11]. Our results were similar to those recommended in the literature. Depending on the anterior chamber depth, this value should be checked periodically to avoid any complications.

Many published peer-reviewed articles have reported a low postoperative ECD value. Several results ranged from 2.5% to 11% loss of ECD that had been mentioned during the short to long-term following the postoperative period [12]. In our investigation, these values showed that the percentage of ECD lost was quite normal. However, it was higher in Group B than in Group A. The difference in the ACD volume and the narrowest anterior chamber depth validates this.

During the entire follow-up period, elevated IOP, endothelial cell loss, and minimal vault values were much higher in the group with a shallow anterior chamber depth.

Conclusion

This study aimed to investigate and analyze the postoperative results of a total of 131 patients (226 eyes) during a 24-month follow-up period. This study aimed to identify any kind of serious complications after implanting phakic IOLs in patients with a shallow anterior chamber depth. Additionally, the feasibility of implanting phakic IOLs in these patient groups was assessed. Phakic IOL (Visian ICL V5) implantation was safe and effective with predictable results in patients with high refractive errors and thin corneas. Furthermore, it provided an alternative approach to refractive surgery. It improved the quality of life of patients with high refractive errors. A shallow anterior chamber depth was one of the main implantation contraindications. Despite this limitation, the study showed that, even in some cases, phakic IOLs could be implanted to correct refractive errors after patient permission and reach high visual results. However, a surprisingly low number of eyes with a shallow ACD underwent follow-up. In patients with a shallow ACD, phakic IOL implantation requires an investigation and a lengthy postoperative follow-up period. This helps to avoid any serious complications, such as secondary glaucoma, ECD loss, and anterior subcapsular cataracts.

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Disclosures

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Disclaimers. *The opinions expressed in this article are solely those of the authors and do not necessarily reflect the official policy or position of their affiliated institutions.*

Data Availability Statement. *The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.*

Abbreviation. *UCVA – Uncorrected visual acuity; BCVA – Best corrected visual acuity; ECD – Endothelial cells density; ACD – Anterior chamber depth; ICL – Implantable collamer lens; IOP – Intraocular pressure; PIOL – Phakic intraocular lens; AC Piol – Anterior chamber phakic intraocular lens; PC Piol – Posterior chamber phakic intraocular lens; RLE – Refractive lens extraction; WHO – World health organization; OCT – Optic coherent tomography; CCT – Central corneal thickness; SE – Spherical Equivalent; SD – Standard deviation.*