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Selection of the Method of Laser Vision Correction for the Treatment of Acquired Ametropia Following Ophthalmic Surgical Procedures

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Abstract: acquired ametropia developing after cataract, refractive, and vitreoretinal surgery remains a significant cause of visual function impairment and requires selection of an optimal enhancement strategy based on previous surgical history, corneal biomechanical status, and the patient's functional demands. A prospective cohort analysis was conducted to evaluate the efficacy, safety, and predictability of three laser enhancement techniques for acquired ametropia in 126 patients after cataract, refractive, and vitreoretinal surgery, with assessment of clinical, topographic, and functional parameters over a 12-month follow-up period. Patients were divided into three clinical groups according to the type of primary intervention, with further subdivision based on the applied laser correction technique, which enabled a differentiated comparative analysis of surface ablation, femtosecond-assisted flap-based technology, and lenticular extraction. The comprehensive evaluation included uncorrected and corrected distance visual acuity, spherical equivalent, contrast sensitivity under photopic and mesopic conditions, tear film stability indices, Ocular Surface Disease Index, as well as corneal topo-tomographic parameters with elevation analysis and ectasia risk assessment. In patients after cataract surgery, the flap-based technique demonstrated the highest refractive predictability, statistically significantly better uncorrected distance visual acuity, and a low residual spherical equivalent while maintaining safe topographic parameters and stable mesopic contrast sensitivity, which is particularly relevant for eyes with implanted intraocular lenses. In the cohort after previous refractive surgery, surface ablation provided the most favorable biomechanical profile, minimal impact on the posterior corneal surface, and the best tear film stability parameters while preserving high functional visual quality, supporting the rationale for a flapless retreatment approach. In patients after vitreoretinal procedures, lenticular technology demonstrated the lowest residual spherical equivalent, the highest contrast sensitivity under mesopic and glare conditions, and the shortest period to normalization of ocular surface symptoms in the absence of clinically significant topographic instability, indicating functional advantages in this cohort. Statistical analysis confirmed the significance of intergroup differences across key parameters at a level of p less than 0.05. The findings demonstrate that the effectiveness of laser enhancement is determined not only by achievement of target refraction but also by comprehensive assessment of optical quality of vision, ocular surface status, and topographic safety. The results substantiate the necessity of an individualized approach to technology selection based on the type of primary intervention and corneal morphofunctional characteristics, thereby improving refractive predictability, minimizing biomechanical risks, and optimizing postoperative recovery of visual function.

Key words: Cataract, Therapeutics, Phacoemulsification, Vitrectomy, Myopia, Cornea

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Introduction

Acquired ametropia (residual myopia, hyperopia, and astigmatism that develop after cataract phacoemulsification with intraocular lens implantation, refractive surgery, vitreoretinal surgery, ocular trauma, or progression of corneal changes) remains a principal cause of reversible visual impairment worldwide. Moreover, its incidence is increasing due to the widespread implementation of surgical methods for the treatment of cataract, refractive pathology, and vitreoretinal disorders. Approximately 670 million individuals are affected by these visual impairments according to data from the World Health Organization [1]. The prevalence of clinically significant postoperative refractive errors after all types of ophthalmic surgery, according to various authors, ranges from 5 to 20 percent of cases [2], even with the use of modern biometric formulas and premium intraocular lenses. Risk factors for the development of acquired ametropia include individual anatomical characteristics of the eye, instability of intraocular lens position, postoperative corneal changes, as well as limitations in the accuracy of preoperative calculations.

In contemporary ophthalmology, several approaches to the correction of acquired ametropia exist, including optical correction, repeat intraocular interventions, and laser enhancement methods. Excimer and femtosecond laser technologies are regarded as the most predictable and minimally invasive methods of enhancement [3], enabling achievement of high refractive accuracy with minimal risk of complications.

However, in addition to their undeniable advantages, all laser correction methods have a number of disadvantages. Transepithelial photorefractive keratectomy (TransPRK) is associated with slow epithelialization and prolonged visual rehabilitation, pronounced pain syndrome in the early postoperative period, an increased risk of subepithelial corneal opacity (haze) in retreatment cases, lower predictability of the result in the early period, limitations regarding the magnitude of possible enhancement (up to 5 diopters), and the necessity for prolonged postoperative treatment [4].

Laser in situ keratomileusis with femtosecond assistance (Femto-LASIK) is associated with interface complications (epithelial ingrowth, transient opacities, flap microstriae), additional stromal thinning after repeat ablation, dependence of the result on the accuracy of flap repositioning, and the impossibility of application in cases of borderline corneal thickness [5, 6].

Keratorefractive lenticule extraction (KLEx) involves technical complexity in performing repeat intrastromal surgery, possible difficulties in lenticule dissection and extraction, transient visual phenomena (halos, fluctuations in visual acuity) [7], lower flexibility in the correction of complex forms of astigmatism, limited possibilities for repeat enhancement, slower stabilization of visual functions compared with LASIK and Femto-LASIK, and the impossibility of performing hyperopic enhancement [8].

Therefore, questions regarding the optimal selection of laser technique, patient selection criteria, and the long-term stability of the obtained results in various clinical situations remain controversial in the literature. This necessitates further research aimed at the systematic evaluation of the efficacy and safety of laser enhancement methods for acquired ametropia [9, 10].

Aim

The aim of this study is to evaluate the efficacy, safety, and predictability of laser enhancement methods for acquired ametropia in patients following cataract, vitreoretinal, and refractive surgery through a comparative analysis of the outcomes of surface ablation, laser in situ keratomileusis with femtosecond assistance, and keratorefractive lenticule extraction in a target group of patients with clinically significant residual refractive errors [11, 12, 13].

Materials and Methods

The study was conducted at the clinical base of the Department of Ophthalmology and Optometry of Postgraduate Education at the Institute of Postgraduate Education of Bogomolets National Medical University at the Medical Center "Ochi Clinic" during the period from 2022 to 2025. A total of 126 patients (126 eyes) with acquired ametropia following surgical treatment of cataract, vitreoretinal pathology, or refractive procedures were enrolled in the study and were divided into three groups. The mean age of the patients was 41.4 ± 2.7 years.

The inclusion criteria were as follows: stable refraction for at least 6 months; availability of refractive data prior to the primary surgery, at one month, at three months, and at six months after the primary surgical intervention; corneal thickness sufficient for laser correction; absence of progressive corneal and retinal diseases; documented information regarding the power and type of intraocular lens implanted during the primary cataract extraction.

The non-inclusion criteria were as follows: active inflammatory ocular disease; decompensated dry eye syndrome; decompensated glaucoma; systemic connective tissue disorders; biomechanical and topographic risk factors, including signs of keratoconus or subclinical ectasia; insufficient residual stromal bed; unstable or progressive refraction; significant

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lens opacities; and systemic contraindications such as active autoimmune diseases, decompensated diabetes mellitus, immunosuppressive therapy, pregnancy, or lactation.

The exclusion criteria were as follows: detected refractive instability at preoperative control measurement, for example clinically significant changes in spherical equivalent or cylinder; progressive suspicion of ectasia or deterioration of topo-tomographic indices, including Belin/Ambrosio Enhanced Ectasia Display deviation value, asymmetry indices, pachymetric profile alterations, and related parameters [13]; inability to obtain reliable and reproducible keratorefractive data due to unstable tear film, poor patient cooperation, inadequate preparation such as failure to observe contact lens washout; and the development of new medical contraindications, including pregnancy, exacerbation of systemic disease, or active keratitis or uveitis.

All patients with acquired ametropia were divided into three groups according to the type of prior surgery: Group 1 included patients with acquired ametropia after cataract surgery (56 eyes), Group 2 included patients with acquired ametropia after refractive surgery (40 eyes), and Group 3 included patients with acquired ametropia after vitreoretinal surgery (30 eyes). Each group was subsequently subdivided into three subgroups depending on the applied method of laser correction of acquired ametropia: Subgroup A included transepithelial photokeratorefractive keratectomy (42 eyes), Subgroup B included laser in situ keratomileusis with femtosecond assistance (43 eyes), and Subgroup C included keratorefractive lenticule extraction (41 eyes). The distribution of patients among the subgroups was performed according to a predefined clinical algorithm that considered the magnitude and structure of residual ametropia, corneal thickness and the predicted ablation profile, parameters of corneal topography including the Belin–Ambrosio deviation index, elevation of the anterior and posterior corneal surfaces, asymmetry indices, and the pachymetric profile, the calculated residual stromal bed, the history of dry eye disease and the risk of postoperative neurotrophic dysfunction, the presence or absence of corneal scars, opacities, or interface changes after previous surgical procedures, as well as the expected recovery profile, including the duration of postoperative rehabilitation, which was discussed with the patient prior to surgery. To increase the reproducibility of the algorithm for selecting the surgical technique, key threshold parameters were documented before surgery, and the decision regarding the method was established prior to the analysis of postoperative outcomes.

Transepithelial photokeratorefractive keratectomy was applied predominantly in cases of limited corneal thickness or when preservation of corneal biomechanical stability was required, in the presence of relatively increased Belin–Ambrosio deviation index values, corneal asymmetry without criteria of manifest ectasia, the presence of dry eye disease, superficial corneal opacities or epithelial irregularities, and a spherical equivalent of enhancement greater than five diopters that did not require a large volume of tissue removal. Laser in situ keratomileusis with femtosecond assistance was used in patients after cataract surgery provided that the Belin–Ambrosio deviation index, elevation parameters, and corneal symmetry remained stable, when rapid visual rehabilitation was required, when high refractive predictability and rapid achievement of maximum uncorrected distance visual acuity were important, and in the absence of signs of epithelial dystrophy or a predisposition to dry eye disease. Keratorefractive lenticule extraction was applied in patients after vitreoretinal surgical procedures in cases where the myopic component of the refractive error predominated and when sufficient corneal thickness was present.

Preoperative examination included determination of uncorrected and best corrected visual acuity using standardized visual acuity charts with documentation of lighting conditions (Huvitz HDR-7000 phoropter); objective and subjective refraction with determination of sphere, cylinder, and axis of astigmatism followed by calculation of the spherical and cylindrical equivalent (Carops CRK-1 autorefractokeratometer); biomicroscopy of the anterior segment of the eye with evaluation of the condition of the corneal epithelium, the tear film, and the presence of corneal opacities (slit lamp Huvitz HS-7000); contrast sensitivity assessment using Pelli–Robson charts under standardized lighting conditions, with testing performed under photopic conditions (eighty five candela per square meter), mesopic conditions (three candela per square meter), and under mesopic illumination with induced glare; examination of the ocular fundus, in the absence of contraindications, in order to exclude active retinal pathology; keratometry, corneal topography and tomography, and pachymetry for analysis of corneal curvature, thickness, and the risk of ectatic changes (Schwind Sirius Plus). Additionally, when indicated, optical coherence tomography of the macula, visual field assessment, intraocular pressure measurement, and evaluation of tear film stability and symptoms of dry eye disease were performed (Optopol REVO FC130, Icare PRO, Huvitz HNP-1P, Optopol PTS 920).

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All measurements were performed at least twice, and in the presence of discrepancies they were repeated three times with subsequent use of the mean value or the most reproducible parameter. This approach reduced the influence of random measurement errors on the planning of ablation and refractive correction.

Surgical intervention and postoperative management: laser enhancement procedures were performed in accordance with protocols approved at the clinical base. Uniform approaches to intraoperative antisepsis, anesthesia, and complication control were applied to all patients. Postoperative management included standard anti-inflammatory and antibacterial therapy with topical medications, lubricating agents, as well as individualized treatment in the presence of symptoms of dry eye disease [14,15,16]. The schedule of follow-up examinations was standardized for all three groups.

Statistical processing was performed using licensed software IBM SPSS Statistics, license number 5725-A54-F23. Statistical analysis was conducted using the software package IBM SPSS Statistics. Quantitative data were presented as mean value plus or minus standard deviation (mean ± standard deviation). Normality of distribution was assessed using the Shapiro–Wilk test. For comparison of the three subgroups, one-way analysis of variance was applied, and in cases of non-normal distribution the Kruskal–Wallis test was used. For multiple comparisons, the Tukey post hoc test with Bonferroni correction was applied. In addition to probability values, the test statistics (F or H) and effect size (partial eta squared) were reported. The level of statistical significance was set at a probability value of less than 0.05. The study was approved by the local bioethics committee, and all patients signed written informed consent for participation in the study. The study had a prospective cohort design. Observations were conducted before surgery and at one, three, six, and twelve months after the intervention in accordance with international clinical guidelines for refractive surgery. All diagnostic and surgical systems used in the present study complied with the current requirements for technical regulation of medical devices, underwent conformity assessment procedures and metrological verification in accordance with the regulatory legal acts of Ukraine, were certified for medical use within the territory of Ukraine, and were operated in accordance with the manufacturer's instructions and the requirements of the quality management system of the medical institution. A complete twelve-month follow-up was available for one hundred eighteen of one hundred twenty six patients, which constituted ninety three point seven percent. Loss to follow-up was six point three percent and did not differ between the groups (probability value equals 0.64).

For the performance of surgical interventions, the following equipment and instruments were used: the Schwind Amaris 750S excimer laser, the Schwind Atos femtosecond laser, and microinstruments produced by MicroSurgical Technology. These included a blunt-tipped irrigation cannula for corneal irrigation after ablation, fine surgical forceps for manipulation of the bandage contact lens, a spatula for lifting the corneal flap, an interface dissection spatula, flap forceps, a vacuum ring integrated into the femtosecond system, a lenticule dissection spatula, a lenticule hook or separator, and microforceps for lenticule extraction.

Results

The baseline characteristics of the groups did not differ statistically (analysis of variance, probability value greater than 0.05), which confirms their comparability before the intervention.

The integrated analysis of the results presented in (Tabl. 2) demonstrated that statistically higher values of uncorrected distance visual acuity were achieved in Subgroup B (0.90 ± 0.20). In addition, the mean residual spherical equivalent in Subgroup B was 0.10 ± 0.25 diopters, indicating high refractive predictability and accuracy of correction. Contrast sensitivity values measured with the Pelli–Robson test (log contrast sensitivity) under mesopic conditions and in the glare mode were statistically higher in Subgroup B (analysis of variance: $F(2,53) = 3.56$; probability value = 0.034), indicating a more favorable optical quality profile under low illumination conditions, which is critically important for patients after implantation of an

Table 1. Baseline characteristics.

Parameter	Group 1	Group 2	Group 3	p
Age (years)	42.1 ± 6.3	39.8 ± 5.9	41.3 ± 6.7	0.34
Central corneal thickness (micrometers)	536 ± 28	528 ± 31	532 ± 30	0.41
Spherical equivalent before surgery (diopters)	−1.85 ± 1.1	−1.72 ± 1.0	−1.94 ± 1.2	0.52
Cylinder (diopters)	−0.92 ± 0.6	−0.88 ± 0.5	−0.95 ± 0.7	0.67
Belin–Ambrosio deviation index (diopters)	0.96 ± 0.42	0.92 ± 0.38	0.99 ± 0.44	0.74

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Table 2. Qualitative and quantitative evaluation of laser correction methods for acquired ametropia in patients of Group 1

Parameter		Group 1		
		Subgroup A (n = 18)	Subgroup B (n = 21)	Subgroup C (n = 17)
PRO (Patient-Reported Outcomes), (score)		0.65 ± 0.08	0.70 ± 0.11	0.55 ± 0.07
Contrast sensitivity, (logCS)	Photopic: Mesopic: Mesopic+glare:	1.85 ± 0.05 1.70 ± 0.05 1.60 ± 0.05	1.90 ± 0.05 1.75 ± 0.05* 1.63 ± 0.07*	1.93 ± 0.03 1.75 ± 0.05 1.65 ± 0.05
Visual acuity (Decimal)		0.85 ± 0.15	0.9 ± 0.2*	0.83 ± 0.25
Spherical equivalent (diopters)		0.38 ± 0.5	0.1 ± 0.25	0.05 ± 0.4
Belin/Ambrosio Enhanced Ectasia Display deviation value (BAD-D) (diopters)		+1.11	+1.2*	+1.83
Corneal elevation of anterior and posterior surfaces (micrometers)	Anterior elevation: Posterior elevation:	−14.24 ± 5.82 −5.4 ± 8.7	Not recorded +4.02 ± 1.81	Not recorded +2.6 ± 2.83
TBUT (Tear break-up time) (seconds)		13 ± 5.18	12.37 ± 4.9	12.8 ± 3.83
OSDI (Ocular Surface Disease Index) (score)		19.0 ± 6.0	21.5 ± 6.5	12.0 ± 4.5

**Note.* A statistically significant difference in indicators was proven at p≤0.05.

intraocular lens. Intergroup comparison of the Belin–Ambrosio deviation index demonstrated statistically significant differences (one-way analysis of variance: F(2,53) = 4.21; probability value = 0.018; partial eta squared = 0.14). At the same time, the absolute values of the Belin–Ambrosio deviation index in all subgroups remained within the clinically safe range. Indicators of tear film stability measured as tear break up time did not differ statistically between the subgroups (probability value = 0.27). Femtosecond assisted laser in situ keratomileusis is characterized by an optimal balance between refractive accuracy, optical quality, and topographic safety, which determines its high effectiveness in the treatment of acquired ametropia after cataract surgery.

The comparative analysis of the clinical and functional parameters presented in (Tabl.3) demonstrated that in patients with acquired ametropia after previous refractive surgery the technique applied in Subgroup A was characterized by the most balanced profile of biomechanical stability and optical quality. The mean values of patient reported outcomes in Subgroup A were 0.55 ± 0.07, which was statistically lower compared with Subgroup B (0.80 ± 0.10) (analysis of variance: F(2,37) = 7.12; probability value = 0.002).

Table 3. Qualitative and quantitative evaluation of laser correction methods for acquired ametropia in patients of Group 2

Parameter		Group 2		
		Subgroup A (n=14)	Subgroup B (n=12)	Subgroup C (n=14)
PRO (Patient-Reported Outcomes), (score)		0.55 ± 0.07*	0.80 ± 0.10	0.50 ± 0.10
Contrast sensitivity, (logCS)	Photopic: Mesopic: Mesopic+glare:	1.90 ± 0.05 1.75 ± 0.05 1.65 ± 0.05	1.85 ± 0.05 1.65 ± 0.05 1.58 ± 0.03	1.95 ± 0.05 1.80 ± 0.08 1.65 ± 0.05
Visual acuity (Decimal)		0.88 ± 0.2*	0.85 ± 0.25	0.83 ± 0.25
Spherical equivalent (diopters)		0.33 ± 0.4	0.13 ± 0.33	0.05 ± 0.5
BAD-D (diopters)		+1.0*	+1.3	+1.8
Corneal elevation of anterior and posterior surfaces (micrometers)	Anterior elevation: Posterior elevation:	−13.02 ± 5.52 −5.62 ± 8.1*	Not recorded +5.0 ± 2.0	Not recorded +2.57 ± 2.8
TBUT (seconds)		14.2 ± 5.8	10.1 ± 4.85	12.95 ± 3.92
OSDI (Ocular Surface Disease Index) (score)		17.5 ± 5.5	25.0 ± 7.0	12.5 ± 4.0

**Note:* A statistically significant difference in indicators was proven at p≤0.05.

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Contrast sensitivity values under photopic (1.90 ± 0.05), mesopic (1.75 ± 0.05), and mesopic with glare (1.65 ± 0.05) conditions were comparable with those obtained using other techniques. The highest mean value of uncorrected distance visual acuity (0.88 ± 0.2) was also recorded in Subgroup A (analysis of variance, probability value = 0.02 compared with keratorefractive lenticule extraction). The Belin–Ambrosio deviation index in Subgroup A was statistically lower compared with the other techniques (one way analysis of variance: F(2,37) = 5.02; probability value = 0.011; partial eta squared = 0.21), which indicates a smaller influence of surface ablation on the corneal topographic and tomographic parameters. The dynamics of posterior corneal surface elevation in Subgroup A (−5.62 ± 8.1 micrometers) did not indicate forward displacement of the posterior surface, in contrast to Subgroup B (+5.0 ± 2.0 micrometers) and Subgroup C (+2.57 ± 2.85 micrometers), with a statistically significant difference between the subgroups (probability value less than 0.001). In addition, the highest indicators of tear film stability (tear break up time 14.2 ± 5.8 seconds) were recorded after transepithelial photokeratorefractive keratectomy. The combination of the presented objective, topographic, and functional parameters indicates that transepithelial photokeratorefractive keratectomy provides an optimal balance of biomechanical safety, posterior corneal surface stability, and preservation of the tear film, which determines its effectiveness in the treatment of acquired ametropia after previous refractive surgery.

The integrated analysis of the clinical and functional parameters presented in (Tabl. 4) demonstrated that the laser correction technique applied in Subgroup C was characterized by the most favorable overall profile in patients with acquired ametropia after vitreoretinal surgery. The mean values of patient reported outcomes in Subgroup C were 0.45 ± 0.05 points, which was lower compared with Subgroup B (0.75 ± 0.07) and comparable with Subgroup A (0.65 ± 0.08), with an intergroup difference that reached statistical significance (analysis of variance, probability value = 0.01). Contrast sensitivity values under photopic (1.95 ± 0.05), mesopic (1.80 ± 0.05), and mesopic with glare (1.70 ± 0.05) conditions were highest in Subgroup C. Despite similar visual acuity values (0.83 ± 0.25), which did not differ statistically from those of the other subgroups (probability value greater than 0.05), keratorefractive lenticule extraction demonstrated the lowest residual spherical equivalent (0.05 ± 0.4 diopters). In Subgroup C, a slightly higher mean value of the Belin–Ambrosio deviation index was observed compared with the other subgroups; however, the difference was moderate in magnitude (one way analysis of variance: F(2,27) = 3.74; probability value = 0.037; partial eta squared = 0.18) and was not accompanied by clinically significant displacement of the posterior corneal surface, remaining within the safe range and not associated with clinically meaningful posterior elevation (+2.6 ± 2.83 micrometers). Indicators of tear film stability (tear break up time 12.8 ± 3.83 seconds) did not differ statistically from those of the other groups (probability value = 0.24), while the most pronounced decrease in the Ocular

Table 4. Qualitative and quantitative evaluation of laser correction methods for acquired ametropia in patients of Group 3

Parameter		Group 3		
		Subgroup A (n=10)	Subgroup B (n=10)	Subgroup C (n=10)
PRO (Patient-Reported Outcomes), (score)		0.65 ± 0.08	0.75 ± 0.07	0.45 ± 0.05*
Contrast sensitivity, (logCS)	Photopic: Mesopic: Mesopic+glare:	1.90 ± 0.05 1.70 ± 0.05 1.60 ± 0.05	1.85 ± 0.05 1.65 ± 0.05 1.55 ± 0.05	1.95 ± 0.05 1.80 ± 0.05* 1.70 ± 0.05*
Visual acuity (Decimal)		0.85 ± 0.22	0.84 ± 0.25	0.85 ± 0.29
Spherical equivalent (diopters)		0.38 ± 0.57	0.13 ± 0.33	0.03 ± 0.57
BAD-D (diopters)		+1.1	+1.3	+1.75*
Corneal elevation of anterior and posterior surfaces (micrometers)	Anterior elevation: Posterior elevation:	−14.44 ± 5.87 −5.82 ± 8.81	Not recorded +6.0 ± 2.5	Not recorded +2.4 ± 2.65
TBUT (seconds)		13.77 ± 5.36	9.89 ± 4.85	13.87 ± 3.83
OSDI (Ocular Surface Disease Index) (score)		20.0 ± 7.0	23.0 ± 8.0	10.5 ± 3.5*

**Note:* A statistically significant difference in indicators was proven at p≤0.05.

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Surface Disease Index was observed in this subgroup (10.5 ± 3.5 points). Keratorefractive lenticule extraction provides an optimal combination of high refractive predictability, stable optical quality under mesopic conditions, and rapid recovery of the ocular surface, which determines its effectiveness in the treatment of acquired ametropia after vitreoretinal surgery.

During the follow up period, no clinically significant complications, such as corneal ectasia or persistent reduction of corrected distance visual acuity by two or more lines, were recorded. In isolated cases, transient subepithelial haze after transepithelial photokeratorefractive keratectomy (7.1 percent) and flap microstriae after femtosecond assisted laser in situ keratomileusis (4.6 percent) were observed, which did not require repeated surgical intervention.

Discussion

The obtained results indicate that the optimal technique is determined not only by achievement of the refractive target expressed as spherical equivalent, but also by functional visual quality, including contrast sensitivity under photopic, mesopic, and mesopic with glare conditions, ocular surface status reflected by tear break-up time and Ocular Surface Disease Index, and topographic safety assessed by the Belin/Ambrosio Enhanced Ectasia Display deviation value and elevation parameters. This underscores the necessity of incorporating patient-reported outcomes and low-contrast testing into the analysis of surgical effectiveness [17].

In patients of Group 1 after cataract surgery, the laser correction technique applied in Subgroup B demonstrated the highest mean uncorrected distance visual acuity (0.90 ± 0.20) and a low residual spherical equivalent (0.10 ± 0.25 diopters), which was statistically significant compared with Subgroup A ($p < 0.05$). Photopic contrast sensitivity values did not differ significantly between groups; however, Subgroup B exhibited a stable profile under mesopic conditions (1.75 ± 0.05), which is clinically relevant considering the interaction between the cornea and the intraocular lens under low illumination. Changes in posterior elevation were moderate (+4.02 ± 1.81 micrometers) and were not accompanied by clinical signs of progressive instability, consistent with published data regarding the topographic safety of enhancement laser in situ keratomileusis. The combination of these factors indicates high refractive predictability in Subgroup B within Group 1 (Tabl.2) [1].

In patients of Group 2 after previous refractive surgery, Subgroup A demonstrated the lowest Patient-Reported Outcomes values (0.58 ± 0.09), significantly better compared with Subgroup B (0.82 ± 0.12), as well as a favorable mesopic contrast sensitivity profile (1.75 ± 0.05). At the same time, the increase in the Belin/Ambrosio Enhanced Ectasia Display deviation value was the lowest (+1.11), and the dynamics of posterior elevation did not indicate forward displacement of the posterior surface (−5.4 ± 8.7 micrometers), suggesting a more conservative biomechanical impact of surface ablation in retreatment cases. These findings are consistent with contemporary evidence supporting the effectiveness of transepithelial photorefractive keratectomy as a safe alternative to flap-based approaches in repeat interventions, particularly when repeat flap lifting is undesirable. Therefore, Subgroup A provides an optimal balance between functional visual quality and topographic stability (Tabl.3).

In Group 3 after vitreoretinal surgery, Subgroup C demonstrated the best mesopic (1.80 ± 0.05) and mesopic with glare (1.70 ± 0.05) contrast sensitivity values ($p < 0.01$), which is of particular importance given the increased susceptibility of these patients to light scattering and contrast reduction. In addition, the time to normalization of the Ocular Surface Disease Index was the shortest (10.5 ± 3.5 score), indicating faster ocular surface recovery. Although the increase in the Belin/Ambrosio Enhanced Ectasia Display deviation value was more pronounced (+1.83), the absolute values remained within the safe range and were not accompanied by clinically significant elevation of the posterior corneal surface (+2.6 ± 2.83 micrometers). Published data confirm that lenticule-based technologies are associated with a more favorable dry eye profile and reduced corneal denervation compared with flap-based techniques, which explains the faster normalization of the Ocular Surface Disease Index and the stability of tear break-up time observed in Subgroup C (Tabl. 4) [10, 11, 18, 19].

Thus, the results of the study demonstrate that the selection of the optimal method for correction of acquired ametropia should be individualized, taking into account the previous surgical history. Femtosecond-assisted laser in situ keratomileusis proved to be the most refractively predictable technique in the post-cataract cohort, as evidenced by improved visual acuity, reduced spherical equivalent, enhanced contrast sensitivity under low illumination conditions, and minimal changes in anterior and posterior corneal elevation. Transepithelial photorefractive keratectomy demonstrated the most favorable biomechanical and subjective profile after previous refractive surgery, supported by superior Patient-Reported Outcomes scores, stable contrast

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sensitivity indices, minimal increase in the Belin/Ambrosio Enhanced Ectasia Display deviation value, and stable anterior and posterior corneal elevation parameters. In contrast, KLEx provided the highest functional quality of vision and faster ocular surface recovery after vitreoretinal interventions, as reflected by improved Patient-Reported Outcomes, superior contrast sensitivity across all illumination modes, high visual acuity values, the lowest residual spherical equivalent, stable tear film parameters, and the shortest period to normalization of the Ocular Surface Disease Index.

Our findings are consistent with contemporary international evidence regarding the effectiveness of laser enhancement after primary refractive surgery. In the study by Moshirfar et al., photorefractive keratectomy enhancement after keratorefractive lenticule extraction achieved high refractive predictability, with 93–100 percent of eyes within ±0.50 diopters of the intended refraction and an efficacy index of approximately 1.03 at 12 months of follow-up, without clinically significant loss of corrected distance visual acuity [20,21]. Similarly, Sia et al., in a retrospective analysis of wavefront-optimized photorefractive keratectomy retreatment after previous photorefractive keratectomy or laser in situ keratomileusis, demonstrated that more than 60 percent of eyes achieved uncorrected distance visual acuity of 20/20 or better, and the majority were within ±0.50 diopters of the target refraction, confirming the stability and safety of surface ablation as an enhancement modality [22].

In the context of flap-based enhancement, Stulting et al. reported that flap lifting after primary laser in situ keratomileusis was associated with a high rate of achieving uncorrected distance visual acuity of 20/25 or better and a target spherical equivalent within ±0.50 diopters, provided that refraction was stable and adequate residual stromal bed thickness was present [23]. At the same time, in patients after keratorefractive lenticule extraction, secondary surface ablation with the use of mitomycin C effectively reduced residual ametropia without inducing clinically significant higher-order aberrations, supporting the feasibility of a combined “small incision lenticule extraction followed by photorefractive keratectomy” strategy when enhancement is required [21, 24].

A systematic review and meta-analysis published in 2025 demonstrated that lenticule-based techniques are associated with a more favorable dry eye profile, including better tear break-up time and Ocular Surface Disease Index scores in the early postoperative period, compared with femtosecond-assisted laser in situ keratomileusis, which is consistent with our observations of faster normalization of the Ocular Surface Disease Index in Subgroup C [25]. Thus, international evidence confirms that both surface and interface-based enhancement techniques provide high refractive accuracy; however, the choice of technology should be based on a differentiated approach that takes into account functional outcomes, topographic safety parameters, and patient-centered endpoints.

It is important to note that although some intergroup differences reached statistical significance, the absolute changes in topographic parameters remained small and did not exceed clinically safe values. This emphasizes that interpretation of the results should take into account not only probability values but also the magnitude of the effect and the clinical significance of the parameters.

Conclusions

In patients after cataract surgery, femtosecond assisted laser in situ keratomileusis demonstrated high levels of refractive predictability and functional visual quality, which allows this technique to be considered an effective option for laser enhancement in this cohort of patients. In cases of acquired ametropia after previous refractive surgery, transepithelial photokeratorefractive keratectomy demonstrated a favorable biomechanical profile and stable functional outcomes, which may indicate the appropriateness of using surface ablation as a method of enhancement in such clinical situations. In patients after vitreoretinal surgical procedures, keratorefractive lenticule extraction demonstrated high values of contrast sensitivity and faster normalization of ocular surface parameters, which allows this technology to be considered a promising approach for laser correction of residual ametropia in this group.

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Вибір методу лазерної корекції зору для лікування набутих аметропій після офтальмохірургічних операцій

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Анотація. Набуті аметропії, що формуються після катарактальної, рефракційної та вітреоретинальної хірургії, залишаються суттєвою причиною зниження зорових функцій та потребують вибору оптимальної стратегії докорекції з урахуванням попереднього хірургічного анамнезу, біомеханічного стану рогівки та функціональних потреб пацієнта. У дослідженні проведено проспективний когортний аналіз ефективності, безпеки та прогнозованості трьох лазерних методик докорекції набутих аметропій у 126 пацієнтів після катарактальної, рефракційної та вітреоретинальної хірургії з оцінкою клінічних, топографічних і функціональних показників упродовж 12 місяців спостереження. Пацієнтів було розподілено на три клінічні групи залежно від типу первинного втручання з подальшим поділом на підгрупи відповідно до застосованої методики лазерної корекції, що дозволило здійснити диференційований порівняльний аналіз поверхневої абляції, клаптевої технології з фемтосекундною підтримкою та лентикулярної екстракції. Комплексна оцінка включала некориговану та максимально кориговану гостроту зору, сферо-циліндричний еквівалент, контрастну чутливість у фотопічних і мезопічних умовах, показники стабільності слізної плівки, індекс симптомів поверхні ока, а також топо-томографічні параметри з аналізом елевації та індексу ризику ектазії. У пацієнтів після катарактальної хірургії методика з формуванням рогівкового клаптя продемонструвала найвищу рефракційну передбачуваність, статистично значуще кращі показники некоригованої гостроти зору та низький залишковий сферичний еквівалент при збереженні безпечних топографічних параметрів і стабільної контрастної чутливості у мезопічних умовах, що має особливе значення для пацієнтів з імплантованою інтраокулярною лінзою. У групі після попередньої рефракційної хірургії поверхнева абляція забезпечила найбільш сприятливий біомеханічний профіль, мінімальний вплив на задню поверхню рогівки та найкращі показники стабільності слізної плівки при збереженні високої функціональної якості зору, що свідчить про доцільність вибору безклаптевої тактики при ретритменті. У пацієнтів після вітреоретинальних втручань лентикулярна технологія продемонструвала найменший залишковий сферичний еквівалент, найвищі показники контрастної чутливості у мезопічних умовах та з режимом засліплення, а також найкоротший період нормалізації симптомів поверхні ока при відсутності клінічно значущих ознак топографічної нестабільності, що вказує на її функціональні переваги у цій когорті. Статистичний аналіз підтвердив достовірність міжгрупових відмінностей за ключовими параметрами при рівні значущості менше 0,05. Отримані дані демонструють, що ефективність лазерної докорекції визначається не лише досягненням цільової рефракції, а й комплексною оцінкою оптичної якості зору, стану поверхні ока та топографічної безпеки. Результати обґрунтовують необхідність індивідуалізованого підходу до вибору технології з урахуванням типу первинного втручання та морфофункціональних характеристик рогівки, що дозволяє підвищити рефракційну передбачуваність, мінімізувати біомеханічні ризики та оптимізувати післяопераційне відновлення зорових функцій.

Ключові слова: катаракта, лікування, факоемульсифікація, вітректомія, міопія, рогівка

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