Research Article / Araştırma Makalesi
doi: 10.18678/dtfd.1278566

Duzce Med J, 2023;25(2):173-178
Düzce Tıp Fak Derg, 2023;25(2):173-178

The Relationship between Kappa Angle and Photic Phenomena after Trifocal Intraocular Lens Implantation

Trifokal Göziçi Lens İmplantasyonu Sonrasında Kappa Açısı ve Fotik Fenomenler Arasındaki İlişki

Hacı KOÇ[1]
0000-0002-5446-8456
Faruk KAYA[2]
0000-0001-9941-0031

[1]Department of Optics and Refraction, Nişantaşı University Health Sciences, İstanbul, Türkiye

[2]Department of Ophthalmology, Medipol University, İstanbul, Türkiye

Corresponding Author
Sorumlu Yazar
Hacı KOÇ
hacikoc@gmail.com

Received / Geliş Tarihi : 07.04.2023
Accepted / Kabul Tarihi : 27.07.2023
Available Online / Çevrimiçi Yayın Tarihi : 13.08.2023

ABSTRACT

Aim: This study aimed to investigate the relationship between photic phenomena and the kappa angle after trifocal lens implantations.
Material and Methods: Fifty eyes of 35 cases, 17 female and 18 male, were included in the study. The kappa angle was calculated with the Lenstar LS900 low-coherence interferometry device using the pupil barycenter parameter. It was also calculated by using the iris barycenter parameters. According to the calculations using the pupil barycenter distance, the patients were divided into two groups with the preoperative pupil barycenter distance below 0.4 mm and above 0.4 mm. A questionnaire was applied to the patients to evaluate complaints and satisfaction in the postoperative period.
Results: The mean preoperative pupil barycenter distance was 0.38±0.12 mm and 52.0% (n=26) of the measurements were below 0.40 mm, while the mean preoperative iris barycenter distance was 0.40±0.15 mm and 46.0% (n=23) of the measurements were below 0.40 mm. No significant correlation was found between the preoperative pupil barycenter distance and the preoperative iris barycenter distance (r_s=0.086, p=0.553). Additionally, there was no statistically significant difference between the two groups concerning symptoms such as halo and glare (p=0.948).
Conclusion: When considering a kappa angle upper limit of 0.6 mm, there is no discernible difference in the frequency of occurrence of photic phenomena. We believe that both iris barycenter parameters and pupil barycenter parameters, utilized for kappa angle calculations, can be effectively employed to determine the deviation distance.
Keywords: Iris barycenter; kappa angle; photic phenomena; pupil barycenter; trifocal intraocular lens.

ÖZ

Amaç: Bu çalışmanın amacı, trifokal lens implantasyonları sonrası fotik fenomen ile kappa açısı arasındaki ilişkiyi araştırmaktır.
Gereç ve Yöntemler: Çalışmaya 17 kadın ve 18 erkek olmak üzere 35 olgunun toplam 50 gözü dahil edildi. Kappa açısı, pupil barycenter parametresi kullanılarak Lenstar LS900 düşük koherens interferometri cihazı ile hesaplandı. Aynı zamanda iris barycenter parametreleri kullanılarak da hesaplandı. Pupil barycenter mesafesi kullanılarak yapılan hesaplamalara göre hastalar ameliyat öncesi pupil barycenter mesafesi 0,4 mm'nin altında olanlar ve 0,4 mm'nin üzerinde olanlar şeklinde iki gruba ayrıldı. Ameliyat sonrası dönemde şikayetleri ve memnuniyetleri değerlendirmek amacıyla hastalara anket uygulandı.
Bulgular: Ameliyat öncesi ortalama pupil barycenter mesafesi 0,38±0,12 mm ve ölçümlerin %52,0'si (n=26) 0,40 mm'nin altında iken, ameliyat öncesi ortalama iris barycenter mesafesi 0,40±0,15 mm ve ölçümlerin %46,0'sı (n=23) 0,40 mm'nin altındaydı. Ameliyat öncesi pupil barycenter mesafesi ile ameliyat öncesi iris barycenter mesafesi arasında istatistiksel olarak anlamlı bir korelasyon yoktu (r_s=0,086, p=0,553). Ek olarak, iki grup arasında halo ve kamaşma gibi semptomlar açısından da istatistiksel olarak anlamlı bir fark yoktu (p=0,948).
Sonuç: Kappa açısı için üst sınır 0,6 mm olarak dikkate alındığında fotik fenomenlerin meydana gelme sıklığında fark edilebilir bir fark yoktur. Kappa açısı hesaplamalarında kullanılan hem iris barycenter parametrelerinin hem de pupil barycenter parametrelerinin sapma mesafesini belirlemek için etkili bir şekilde kullanılabileceğine inanıyoruz.
Anahtar kelimeler: Iris barycenter; kappa açısı; fotik fenomen; pupil barycenter; trifokal intraoküler lens.

INTRODUCTION

After the widespread adoption of multifocal intraocular lenses (MIOLs) in cataract surgery, achieving perfection and flawless outcomes has become crucial. These lenses are commonly used for cataract and presbyopia surgeries, leading to rising expectations and demands. While many studies have reported positive results, certain issues persist (1). MIOLs have the ability to focus at various depths within the optical zone (2). They are designed to distribute light to different distances, using either refractive or diffractive optics (3). Trifocal intraocular lenses (IOLs), a new generation of MIOLs, possess a third focus that enhances intermediate vision while maintaining performance for near and far vision (4). Although MIOLs can provide spectacle-free vision, they may reduce contrast sensitivity and cause unwanted photic phenomena like glare and halos due to light passing through diffractive optics (5,6).

Studies in the past have pointed out various reasons for photic phenomena following MIOL implantations, including IOL decentralization, lens fragment residues, posterior capsule opacification, dry eye syndrome, uncorrected visual acuity, postoperative astigmatism, and postoperative ametropia (1,7,8). More recently, it has been suggested that MIOLs may induce higher aberrations, glare, and halos in patients with a high kappa angle (1).

The kappa angle represents the angle between the visual axis and the pupillary axis (9). It can be classified as positive (nasal light reflection) or negative (temporal light reflection). A positive kappa angle of up to 5° is considered physiological, whereas higher angles may result in pseudo-strabismus (10).

In this study, we aimed to examine the occurrence of photic phenomena in patients who have undergone trifocal lens implantation and investigate its relationship with the kappa angle.

MATERIAL AND METHODS

Study Design and Patients

This retrospective study was conducted at Kütahya Anadolu Hospital between 2017 and 2019, following the principles of the Helsinki Declaration. Approval for the study was obtained from the İstanbul Medipol University Ethics Committee (Date: 08.11.2019, Approval No: 61009), and written informed consent was obtained from all participating patients. The study included patients who were diagnosed with cataracts during their ophthalmologic examinations, and who willingly underwent cataract surgery with the desire for trifocal lens implantation. Each eye was treated as an individual case, and all examinations were conducted monocularly. Acrysof IQ PanOptix lenses (Alcon Laboratories, Inc.) were used for all patients in the study. The patients were categorized into two groups based on their preoperative kappa angle measurements: the first group included those with a preoperative kappa angle below 0.40 mm, while the second group comprised those with a measurement of 0.40 mm and above.

Inclusion and Exclusion Criteria

Patients with cataracts, corneal astigmatism of 1.00 D and below, and IOL strength between +16 D and +26.5 D were included in the study.

Patients with corneal astigmatism values above 1.00 D, irregular astigmatism, corneal dystrophy, dry eye syndrome, pupillary abnormality, glaucoma or intraocular inflammation history, macular disease, retinopathy, neuro-ophthalmic disease and patients with intraoperative or postoperative complications were not included in the study.

Acrysof IQ PanOptix

Acrysof IQ PanOptix lenses are non-apodized diffractive trifocal IOLs. In eyes with both small pupils and large pupils, it has the ability to distribute light to four focal points for near distance, intermediate distance, and far distance vision. The light passing through the lens is divided into two. Half fall to the distant focal point and the other half to the near to intermediate distance focal point. The lens has a diffraction zone of 4-5 mm. In this way, its performance is completely free from the size of the pupil. It is produced from hydrophobic acrylic material. The diameter of the optical body of IOL is 6 mm and has a total diameter of 13 mm (3).

Preoperative Assessment

All patients underwent a full ophthalmological examination preoperatively. Uncorrected distance visual acuity (UDVA), corrected distance visual acuity (CDVA), manifest refractions, slit-lamp biomicroscopic examinations, non-contact tonometric examinations, and fundoscopic examinations were performed. IOL power was calculated using the SRK-II formula. The strength of all IOLs was calculated by targeting emmetropia. All values were obtained by Lenstar LS 900 (Haag-Streit AG, Koeniz, Switzerland) optical low-coherence reflectometry. This device does not automatically measure the angle of kappa. The distance between the corneal vertex and the center of the pupil (x and y Cartesian values) is measured by the Lenstar LS 900. After measuring the pupil barycenter with the device (x and y coordinates of pupil, dx, and dy), we calculated the kappa angle with the Pythagorean theorem. We called this deviation distance pupil barycenter distance (PBD). We also calculated the angle using the distance between the corneal vertex and the iris center using the same theorem and iris barycenter values. We called this deviation distance iris barycenter distance (IBD).

Surgical Procedure

All surgeries were performed under topical anesthesia by the same surgeon (HK). Surgical operations were completed without complications, and sutures, and were performed using a standard phacoemulsification technique with a superior corneal incision of 2.8 mm. All IOLs were implanted with an injector from the edge of the incision. As a postoperative medication, 0.5% moxifloxacin, 0.1% dexamethasone, 0.5% ketorolac, and lubricant drops were used when needed.

Postoperative Assessment

Postoperative examinations were performed on the 1st day, 1st week, 1st month, and 6th month. In the 6th month, manifest refraction, monocular and binocular UDVA from 6 m, CDVA, 40 cm, and 60 cm near vision, and intermediate distance visual acuity examinations were performed. Near and intermediate distance vision examinations were performed with N-type notation. At the postoperative 6th month, pupil barycenter distance and iris barycenter distance measurements were also determined in mm with the Lensstar LS 900 device. Patients were called and a questionnaire was applied to patients. When the

general satisfaction with the operation was questioned, it was evaluated as 5: excellent, 4: very good, 3: good, 2: not bad, 1: bad, and 0: very bad. Scoring according to the spectacle needs was evaluated as 3: having no need for spectacle, 2: needing spectacle during some activities, (such as reading, driving), and 1: constantly needing spectacle for daily activities. Preoperatively, patients were shown photic phenomena such as halo, glare, and starbursts with pictures, and they were told that these symptoms may occur after the operations. Scoring postoperatively for photic phenomena, 5: no symptoms, 4: no disturbing, mild symptoms, 3: symptoms that moderately disturb during some activities (such as driving, looking at light) but do not cause the activity to stop or change its tempo, 2: moderate symptoms that cause to change the tempo of the activity, requiring extra effort for the continuation of the activity, and 1: severe symptoms that would require avoiding or abandoning the activity completely.

Statistical Analysis

Number Cruncher Statistical System (NCSS) 2007 (Kaysville, Utah, USA) program was used for statistical analysis. Descriptive statistical methods (mean, standard deviation, median, minimum, maximum, frequency, and percentage) were used when evaluating the data. The suitability of quantitative data for normal distribution was tested by the Shapiro-Wilk test and graphical examinations. Student's t test was used for the comparison of the quantitative variables with normal distribution between the two groups, and the Mann-Whitney U test was used for the comparison of the quantitative variables without normal distribution between the two groups. Wilcoxon Signed Ranks test was used for preoperative and postoperative comparisons of variables that did not show normal distribution. In the comparison of qualitative data, the Pearson chi-square and Fisher-Freeman-Halton tests were used. Statistical significance was accepted as $p<0.05$.

RESULTS

The study included a total of 50 eyes of 35 cases, of which 48.6% (n=17) were female and 51.4% (n=18) were male. The ages of the cases ranged between 26 and 85, with a mean of 59.23±14.94 years. While 57.1% (n=20) of the cases were studied with only one eye, 42.9% (n=15) were included in the study with both eyes. The distribution of some preoperative and postoperative data of the cases were shown in Table 1.

The mean preoperative pupil barycenter distance was 0.38±0.12 mm, the measurement of 52.0% (n=26) of the cases was below the median value of 0.40 mm, and the measurement of 48.0% (n=24) was 0.40 mm or above. The mean postoperative pupil barycenter distance was 0.30±0.14 mm. The change in postoperative pupil barycenter distance measurement compared to the preoperative was statistically significant (p=0.001, Table 2).

The mean preoperative iris barycenter distance was 0.40±0.15 mm, the measurement of 46.0% (n=23) of the cases is below the median value of 0.40 mm, and the measurement of 54.0% (n=27) is 0.40 mm or above. The mean postoperative iris barycenter distance was 0.41±0.18 mm. The change in postoperative iris barycenter distance compared to the preoperative was not statistically significant (p=0.901, Table 3).

Table 1. Distribution of preoperative and postoperative data

Preoperative	**Mean±SD**	**Median (min-max)**
Axial length (mm)	23.44±1.07	23.5 (21.5 - 25.3)
Mean keratometry (D)	43.76±1.63	43.7 (38.7 - 47.6)
ACD (mm)	3.32±0.35	3.3 (2.6 - 4.2)
IOL power (D)	21.44±3.26	21 (16 - 29)
UDVA (logMAR)	0.49±0.28	0.5 (0.1 - 1.2)
SE (D)	-0.71±3.13	-0.1 (-9.9 - 3.5)
Corneal astigmatism (D)	0.35±0.63	0.6 (-1 - 1)
Postoperative	**Mean±SD**	**Median (min-max)**
SE (D)	0.40±0.48	0.4 (-1.5 - 1.4)
Corneal astigmatism (D)	0.56±0.43	0.5 (-0.5 - 1.4)
UNVA 40 cm (logMAR)	0.11±0.08	0.1 (0 - 0.4)
UIVA 60 cm (logMAR)	0.17±0.09	0.2 (0 - 0.4)
UDVA 4 m (logMAR)	0.13±0.19	0.1 (0 - 0.9)
CNVA 40 cm (logMAR)	0.05±0.06	0 (0 - 0.2)
CIVA 60 cm (logMAR)	0.11±0.09	0.1 (0 - 0.3)
CDVA 4 m (logMAR)	0.01±0.03	0 (0 - 0.2)

ACD: anterior chamber depth, IOL: intraocular lense, UDVA: uncorrected distance visual acuity, SE: spherical equivalent, UNVA: uncorrected near visual acuity, UIVA: uncorrected intermediate visual acuity, CNVA: corrected near visual acuity, CIVA: corrected intermediate visual acuity, CDVA: corrected distance visual acuity, D: dioptri, mm: millimeter, SD: standard deviation, min: minimum, max: maximum

Table 2. Evaluation of pupil barycenter measurements preoperative and postoperative

	Preoperative		**Postoperative**		**p**
	Mean±SD	**Median (min-max)**	**Mean±SD**	**Median (min-max)**	
Pupil barycenter X (mm)	-0.09±0.33	-0.3 (-0.5 - 0.6)	0.01±0.29	0 (-0.5 - 0.5)	**0.035**
Pupil barycenter Y (mm)	-0.03±0.20	0 (-0.5 - 0.3)	-0.09±0.15	-0.1 (-0.5 - 0.2)	**0.048**
Pupil barycenter distance (mm)	0.38±0.12	0.4 (0.1 - 0.6)	0.30±0.14	0.3 (0.1-0.6)	**0.001**
	<0.40	**≥0.40**	**<0.40**	**≥0.40**	
Pupil barycenter distance, n (%)	26 (52.0)	24 (48.0)	38 (76.0)	12 (24.0)	

Table 3. Evaluation of iris barycenter measurements preoperative and postoperative

	Preoperative		**Postoperative**		**p**
	Mean±SD	**Median (min-max)**	**Mean±SD**	**Median (min-max)**	
Iris barycenter X (mm)	-0.01±0.39	0.1 (-0.7 - 0.7)	0.03±0.40	0.1 (-0.7 - 0.8)	0.480
Iris barycenter Y (mm)	0.07±0.16	0.1 (-0.3 - 0.6)	0.02±0.20	0 (-0.3 - 0.5)	0.104
Iris barycenter distance (mm)	0.40±0.15	0.4 (0.1 - 0.7)	0.41±0.18	0.5 (0.1-0.8)	0.901
	<0.40	**≥0.40**	**<0.40**	**≥0.40**	
Iris barycenter distance, n (%)	23 (46.0)	27 (54.0)	20 (40.0)	30 (60.0)	

Table 4. The results of the questionnaire in terms of preoperative pupil barycenter distance (kappa angle)

	<0.40 mm (n=26)	**≥0.40 mm (n=24)**	**p**
General satisfaction, n (%)			
Very bad	1 (3.8)	0 (0.0)	0.224
Good	2 (7.7)	2 (8.3)	
Very good	11 (42.3)	16 (66.7)	
Perfect	12 (46.2)	6 (25.0)	
Spectacle requirement, n (%)			
Always	2 (7.7)	2 (8.3)	0.879
Sometimes	3 (11.5)	4 (16.7)	
Never	21 (80.8)	18 (75.0)	
The relationship between symptom and activity, n (%)			
Causes to change the tempo of activity, moderate symptom	1 (3.8)	1 (4.2)	0.948
Does not cause to change the tempo of activity, moderate symptom	1 (3.8)	2 (8.3)	
Mild symptom	15 (57.7)	14 (58.3)	
No symptom	9 (34.6)	7 (29.2)	

There was no statistically significant correlation between pupil barycenter distance and iris barycenter distance preoperatively (Spearman's rho, r_s=0.086 p=0.553), and postoperatively (r_s=0.266 p=0.062).

When the patients were asked about their general satisfaction after the surgery, 2.0% (n=1) responded very bad, 8.0% (n=4) good, 54.0% (n=27) very good, and 36.0% (n=18) perfect. While 8.0% (n=4) of the patients constantly need spectacle after surgery, 14.0% (n=7) do not need spectacle during some activities, and 78.0% (n=39) do not need spectacle at all. Moderate symptoms caused a change of activity tempo in 4.0% (n=2) of cases, moderate symptoms did not cause a change of activity tempo in 6.0% (n=3), and mild symptoms occurred in 58.0% (n=29), no symptoms were observed in 32.0% (n=16). According to the groups, overall satisfaction (p=0.224), spectacle need (p=0.879) and symptoms (p=0.948) do not differ statistically (Table 4).

DISCUSSION

With the development of new types of IOLs, the kappa angle has begun to be at the forefront among the subjects that cataract surgeons are interested in (1). We carried out this study over the kappa angle. We evaluated the angle of kappa both on the pupil center (pupil barycenter distance) and on the iris center (iris barycenter distance).

In eyes with a positive kappa angle, the pupillary axis is located temporally than the visual axis. In eyes with a negative kappa angle, the pupillary axis is located in the nasal relative to the visual axis. Thus, when an eye is fixed on any light source, the reflection on the surface of the cornea will not be in the center. It will be nasal in eyes with a positive kappa angle and temporal in eyes with a negative kappa angle (1).

Some studies have reported that if the angle of kappa is high (>0.6 mm), even if the IOL is centralized, halo and glare may occur (11). Therefore, it is important to evaluate the kappa angles before trifocal lens implantations. Devices such as Synoptophere, Orbscan II, Galilei, and OPD Scan II were used to detect the Kappa angle. Lenstar LS 900 device can be used for kappa angle calculations (11-13). This device does not automatically measure the kappa angle but can be calculated using the Pythagorean theorem after pupil barycenter values (x and y coordinates of pupil, dx, and dy) have been determined. With the same theorem, we calculated the angle on the iris barycenter.

MIOL designs have made significant progress since their introduction to the market. Patient satisfaction has increased significantly with these new models (14,15). Neuro-adaptation can play a very important role in some cases. Therefore, sufficient time should be provided before making a conclusion about the intensity of photic phenomena (16,17). Blurred vision and photic phenomena are the most common causes of patient dissatisfaction after MIOL implantation (18). The most important causes of dissatisfaction in patients with MIOL, causing the appearance of a halo, glare, and other negative photic phenomena, are ametropia and posterior capsule opacity. Qi et al. (19) stated that the incidence of glare and halo was associated with an increase in the kappa angle. In a study, it was reported that the diameter of the central region of the lens and biometric values may cause a high kappa angle, which may lead to the formation of negative photic phenomena (1).

Moderate photic phenomena caused the change of activity tempo in 4.0% of the cases included in our study, moderate photic phenomena did not cause the change of activity tempo in 6.0%, mild photic phenomena in 58.0%, and no symptoms were observed in 32.0%. 80% of the cases stated those did not experience any distress in terms of photic phenomena or those who experienced discomforts at a level that would not change the tempo of activity.

Some researchers have suggested that the light will pass through the center of the IOL and reach the center of the macula in small kappa-angled eyes. However, in wide kappa-angled eyes, the light can pass through diffractive rings, causing negative photic phenomena such as halo and glare (18). A wide kappa angle can cause misalignment between the MIOL center and the visual or optical axes. This can lead to the functional decentralization of the MIOL (19). Previous studies have reported that photic phenomena that occur after cataract surgery are associated with shifts in IOLs. In another study, it was reported that wide kappa angles can also cause halo and glare. They also reported that the intensity of the halo felt was correlated with the kappa angle and postoperative uncorrected visual activity. However, they also suggested that glare, halo, and other negative photic phenomena never appeared after surgery in some wide-angle patients (14).

The relation between the kappa angle and halo and glare is not fully understood (19). In a study using the standard ray-tracing technique, it has been reported that a shadow is formed between retinal images when a gap occurs between the rays that miss the IOL and the rays that are reflected from the IOL. In another study, it was suggested that if the kappa angle is wide, the light enters the eye through different diffraction rings, and thus negative photic phenomena can occur (20).

There was no statistically significant difference in terms of overall satisfaction, spectacle requirement, and photic phenomena according to the groups in our study. According to the kappa angle calculations made on the pupil barycenter, there is no significant difference in terms of photic phenomena between the group with a distance above 0.4 mm and the group below 0.4 mm, provided that the upper limit is 0.6 mm.

Kappa angle measurements using the pupil barycenter preoperatively are 0.38±0.12 mm. The results of 52.0% of the cases were below the median value of 0.40 mm, and the results of 48.0% were 0.40 mm and above. The mean kappa angle measurement results using the pupil barycenter postoperatively are 0.30±0.14 mm. Angle measurement results using the iris barycenter preoperatively were 0.40±0.15 mm. The results of 46.0% of the cases were below the median value of 0.40 mm, and the results of 54.0% were 0.40 mm and above. The mean postoperative iris barycenter was 0.41±0.18 mm. Since preoperative values are more important in terms of operation preparation, we see that the kappa angle values using the pupil barycenter and iris barycenter are close to each other.

Now more and more surgeons are paying attention to the kappa angle and the alpha angle. Interestingly, it was found that the alpha angle, defined as the intersection of the visual axis with the optical axis, is correlated with the IOL tilt, similar to the kappa angle (21). In eyes with a kappa or alpha angle less than 0.5 mm, the kappa angle has a greater effect in terms of postoperative visual quality parameters. Care should be taken in the use of trifocal lenses in eyes with a kappa or alpha angle greater than 0.5 mm (22).

Chord mu definition has started to be accepted as a new reference mark to be used in this context. Defines the displacement between the subject-fixated coaxially sighted corneal light reflex and the center of the pupil (23). In a study, it was reported that apparent chord mu values were higher in hyperopia compared to myopia (24).

We consider the fact that the number of cases we enrolled in our study is not too high and that we can operate on only one eye of some patients as factors that limit our study.

CONCLUSION

Regarding photic phenomena, a safe kappa angle limit of 0.6 mm can be considered. When the preoperative kappa angle value is below 0.6 mm, photic phenomena typically do not occur or do not significantly impact daily activities. Additionally, we believe that iris barycenter values, along with pupil barycenter values used for kappa angle determination, could serve as supplementary parameters. However, large sample studies are necessary to draw definitive conclusions.

Ethics Committee Approval: The study was approved by the Non-interventional Clinical Research Ethics Committee of Medipol University (08.11.2019, 61009).

Conflict of Interest: None declared by the authors.

Financial Disclosure: None declared by the authors.

Acknowledgments: None declared by the authors.

Author Contributions: Idea/Concept: HK; Design: HK, FK; Data Collection/Processing: HK, FK; Analysis/Interpretation: HK, FK; Literature Review: HK, FK; Drafting/Writing: HK, FK; Critical Review: HK, FK.

REFERENCES

1. Karhanová M, Pluháček F, Mlčák P, Vláčil O, Šín M, Marešová K. The importance of angle kappa evaluation for implantation of diffractive multifocal intra-ocular lenses using pseudophakic eye model. Acta Ophthalmol. 2015;93(2):e123-8.
2. Marques EF, Ferreira TB. Comparison of visual outcomes of 2 diffractive trifocal intraocular lenses. J Cataract Refract Surg. 2015;41(2):354-63.
3. Cochener B, Boutilier G, Lamard M, Auberger-Zagnoli C. A comparative evaluation of a new generation of diffractive trifocal and extended depth of focus intraocular lenses. J Refract Surg. 2018;34(8):507-14.
4. Carballo-Alvarez J, Vazquez-Molini JM, Sanz-Fernandez JC, Garcia-Bella J, Polo V, García-Feijoo J, et al. Visual outcomes after bilateral trifocal diffractive intraocular lens implantation. BMC Ophthalmol. 2015;15:26.
5. de Vries NE, Nujits RM. Multifocal intraocular lenses in cataract surgery: literature review of benefits and side effects. J Cataract Refract Surg. 2013;39(2):268-78.
6. de Vries NE, Wabers CA, Touwslager WR, Bauer NJ, de Brabander J, Berendschot TT, et al. Dissatisfaction after implantation of multifocal intraocular lenses. J Cataract Refract Surg. 2011;37(5):859-65.
7. Woodward MA, Randleman JB, Stulting RD. Dissatisfaction after multifocal intraocular lens implantation. J Cataract Refract Surg. 2009;35(6):992-7.
8. Walkow T, Klemen UM. Patient satisfaction after implantation of diffractive designed multifocal intraocular lenses in dependence on objective parameters. Graefes Arch Clin Exp Ophthalmol. 2001;239(9):683-7.
9. Domínguez-Vicent A, Monsálvez-Romín D, Pérez-Vives C, Ferrer-Blasco T, Montés-Micó R. Measurement of angle kappa with Orbscan II and Galilei G4: effect of accomodation. Graefes Arch Clin Exp Ophthalmol. 2014;252(2):249-55.
10. Zarei-Ghanavatti S, Gharae H, Eslampour A, Abrishami M, Ghasemi-Moghadam S. Angle kappa changes after photorefractive keratectomy for myopia. Int Ophthalmol. 2014;34(1):15-8.
11. Cankaya C, Ozsoy E, Demirel EE, Polat N, Gunduz A. Estimation of angle kappa and pupil barycentre configuration in myopic tilted disc syndrome. Clin Exp Optom. 2020;103(2):192-6.

12. Park CY, Oh SY, Chuck RY. Measurement of angle kappa and centration in refractive surgery. Curr Opin Ophthalmol. 2012;23(4):269-75.
13. Basmak H, Sahin A, Yildirim N, Papakostas TD, Kanellopoulos AJ. Measurement of angle kappa with synoptophore and Orbscan II in a normal population. J Refract Surg. 2007;23(5):456-60.
14. Prakash G, Prakash DR, Agarwal A, Kumar DA, Agarwal A, Jacob S. Predictive factor and kappa angle analysis for visual satisfactions in patients with multifocal IOL implantation. Eye (Lond). 2011;25(9):1187-93.
15. Cillino S, Casuccio A, Di Pace F, Morreale R, Pillitteri F, Cillino G, et al. One-year outcomes with new-generation multifocal intraocular lenses. Ophthalmology. 2008;115(9):1508-16.
16. Palomino Bautista C, Carmona González D, Castillo Gómez A, Bescos JA. Evolution of visual performance in 250 eyes implanted with the Tecnis ZM900 multifocal IOL. Eur J Ophthalmol. 2009;19(5):762-8.
17. Buznego C, Trattler WB. Presbyopia-correcting intraocular lenses. Curr Opin Ophthalmol. 2009;20(1):13-8.
18. Moshifar M, Hoggan RN, Muthappan V. Angle kappa and its importance in refractive surgery. Oman J Ophthalmol. 2013;6(3):151-8.
19. Qi Y, Lin J, Leng L, Zhao G, Wang Q, Li C, et al. Role of angle κ in visual quality in patients with a trifocal diffractive intraocular lens. J Cataract Refract Surg. 2018;44(8):949-54.
20. Holladay JT, Simpson MJ. Negative dysphotopsia causes and rationale for prevention and treatment. J Cataract Refract Surg. 2017;43(2):263-75.
21. Fu Y, Kou J, Chen D, Wang D, Zhao Y, Hu M, et al. Influence of angle kappa and angle alpha on visual quality after implantation of multifocal intraocular lenses. J Cataract Refract Surg. 2019;45(9):1258-64.
22. Wang R, Long T, Gu X, Ma T. Changes in angle kappa and angle alpha before and after cataract surgery. J Cataract Refract Surg. 2020;46(3):365-71.
23. Holladay JT. Apparent chord mu and actual chord mu and their clinical value. J Cataract Refract Surg. 2019;45(8):1198-9.
24. Koc H, Kaya F. Pupil barycenter configuration in patients with myopia and hyperopia. Int Ophthalmol. 2022;42(11):3441-7.