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Changes in Chord Mu (µ) Length Before and After Cataract Surgery

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ABSTRACT

Objective: Comparison of chord µ length, a potential marker that may gain importance especially in multifocal lens implantation, before and after phacoemulsification surgery and intraocular lens (IOL) implantation in patients with cataracts.

Methods: This retrospective study included 33 eyes of 33 patients who underwent phacoemulsification surgery between December 2022 and February 2023. Corneal topography (Pentacam HR, Oculus, Wetzlar, optikgerate GmbH) was performed on each patient before and after surgery. The values obtained before and at least 3 months after surgery were compared using the Student-t test. **Results:** There were 18 (54.5%) males and 15 (45.5%) females among the 33 patients who participated in the study. The average age was 67.27 ± 10.93 years. The postoperative mean chord µ lenght was significantly lower than the preoperative mean chord µ lenght (p=0.002). Additionally, the mean postoperative pupil size was significantly lower than the mean preoperative pupil size (p=0.000). There is a weak positive relationship between the change in chord µ length and the change in pupil size, but this relationship is not statistically significant (p>0.05). No statistically significant relationship was found between any of the other binary variables. **Conclusion:** Centralization is crucial in refractive surgery and multifocal IOL implantation to prevent high-order aberrations and photic phenomena. Therefore, it seems useful for surgeons to be familiar with chord µ measurements, especially regarding surgical preparation. It should be considered that changes in chord mu values may influence the development of photic phenomena. A decrease in chord mu after phacoemulsification may assist the surgeon in the preoperative decision-making process in patients at risk of photic phenomena or in patients with borderline values**.**

Keywords: Phacoemulsification, Intraocular Lens Implantation, Chord Mu, Angle Kappa.

Katarakt Cerrahisi Öncesi ve Sonrası Chord Mu (µ) Uzunluğundaki Değişim

ÖZ

Amaç: Kataraktlı hastalarda fakoemülsifikasyon cerrahisi ve göz içi lens (GİL) implantasyonundan önce ve sonra, özellikle çok odaklı lens implantasyonunda önem kazanabilecek potansiyel bir belirteç olan chord µ uzunluğunun karşılaştırılması. **Gereç ve yöntem:** Retrospektif olarak yürütülen bu çalışmada Aralık 2022- Şubat 2023 tarihleri arasında fakoemülsifikasyon cerrahisi yapılan 33 hastanın 33 gözü çalışmaya dahil edilmiştir. Her olguya ameliyat öncesinde ve sonrasında kornea topografisi testi (Pentacam HR, Oculus, Wetzlar, optikgerate GmbH) uygulanmıştır. Ameliyat öncesi ve en az 3 ay sonrası elde edilen değerler Student-t testi ile karşılatırılmıştır. **Bulgular:** Çalışmaya dahil edilen 33 hastanın %54.5'i erkek (n=18) ve %45.5'i kadın (n=15) idi. Yaş ortalaması 67.27 ± 10.93 yıl olarak hesaplandı. Ameliyat sonrası chord µ ortalaması ameliyat öncesi chord µ ortalamasına göre istatistiksel olarak anlamlı bir şekilde daha düşük bulunmuştur (p=0.002). Ameliyat sonrası pupil büyüklüğü ortalaması ameliyat öncesi ortalamasına göre istatistiksel olarak anlamlı bir şekilde daha düşük bulunmuştur (p=0.000). Chord µ uzunluğundaki değişim ile pupil büyüklüğündeki değişim arasında zayıf pozitif bir ilişki olup bu ilişki istatistiksel anlamlılığa ulaşmamaktadır (p>0.05). Diğer ikili değişkenlerin hiçbiri arasında istatistiksel olarak anlamlı bir ilişki tespit edilememiştir. **Sonuç:** Doğru santralizasyon, hem refraktif cerrahide hem de multifokal GİL implantasyonunda, yüksek dereceli aberasyonları ve fotik fenomenlerin oluşmasını önlemek için önemlidir. Bu nedenle cerrahların, özellikle cerrahi hazırlık ile ilgili olarak, chord µ ölçümlerine aşina olmaları faydalı görünmektedir. Chord mu değerlerindeki değişikliklerin fotik fenomenlerin oluşumuna etki edebileceği gözönünde bulundurulmalıdır. Fakoemülsifikasyon sonrası chord mu değerlerinin azalıyor olması fotik fenomen oluşumu riski olan veya sınır değerdeki hastalarda preoperative karar verme sürecinde cerraha yardımcı olabilir.

Anahtar Kelimeler: Fakoemülsifikasyon, Göz İçi Lens İmplantasyonu, Chord Mu, Kappa Açısı.

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INTRODUCTION

In recent years, the range of intraocular lens (IOL) options used in phacoemulsification has expanded significantly. Especially in the use of trifocal and extended depth of focus IOLs, ensuring optimum visual results and minimizing photic events such as glare and halo requires good IOL centralization (Chang & Waring, 2014; Park et al., 2012; Prakash et al., 2011). Particularly in patients undergoing IOL implantation for refractive purposes, dysphotopsia, glare and halos are the most common causes of postoperative dissatisfaction. (de Vries et al., 2011). In order to prevent these complaints and to choose the right IOL, the visual axes and the angles formed between them (kappa, lambda and alpha) were examined in depth (Chang & Waring, 2014; Schwiegerling, 2013). It is known that in the presence of a wide-angle kappa, diffractive images deteriorate and the postoperative dysphotopic phenomenon increases. Anterior segment diagnostic devices such as corneal topography, which are frequently used for preoperative refractive planning, take a 2-dimensional image of the anterior segment while the eye is fixed coaxially to the light source (Mandell, 1995; Rodríguez-Vallejo et al., 2019). The devices process this image and estimate the distance between the vertex normal (Purkinje-Sanson reflection) and the center of the pupil. Thus, the 2-dimensional displacement between the vertex normal and the pupil center is measured instead of the true kappa angle. Since both parameters are widely confused in clinical use, Chang and Waring defined a new term, chord μ, to express this 2-dimensional displacement (Rodríguez-Vallejo et al., 2019). Chord μ length refers to the 2-dimensional distance between the corneal light reflex and the pupillary center, which refers to the distance between 2 points rather than angles (Chang & Waring, 2014; Holladay et al., 2017). In advance, Holladay defined the difference between the apparent chord μ (the distance between the Purkinje image and the center of the pupil viewed from the cornea) and the actual chord μ (the value measured at the pupil level, unaffected by the magnifying effect of the cornea) (Holladay, 2019). Some corneal topography devices, such as Pentacam, can measure the actual chord μ length. Studies in the literature have examined the distribution and determinants of the kappa angle in depth, however, studies on chord μ are quite limited. Therefore, this study aimed to compare chord μ length before and after cataract surgery.

MATERIALS AND METHODS

Participants

This retrospective study was carried out at Karamanoglu Mehmetbey University Ophthalmology Clinic. Patients who underwent phacoemulsification surgery between December 2022 and February 2023 were included in this study.

Inclusion criteria were as follows: 1. Absence of corneal or lens opacity that would prevent anterior and posterior segment imaging, 2. Corneal astigmatism below 1 diopter. Cataract cases with a non-nuclear component were not included in the study as they may affect image quality. A cut-off value for spherical refractive error was not determined because of the myopic effect of nuclear cataract. Instead, the relationship between the change in chord mu and axial length was statistically evaluated. Patients with pseudoexfoliation syndrome and those with a history of alpha-adrenergic antagonist use were excluded from the study. Cases with any ocular disease besides cataract, suspected keratoconus, previous eye surgery, low cooperation, intraoperative iris damage and IOL decentralization during follow-up were excluded. Thirty-three eyes of 33 patients were enrolled.

Procedure

Preoperative evaluation was performed in 10 days before operation, and postoperative evaluation was performed at the earliest 3 months after surgery. All patients were evaluated in terms of visual acuity, biomicroscopic anterior segment and posterior segment findings and in addition, intraocular pressure measurement, optical coherence tomography (NIDEK RS3000 Advance, NIDEK CO., LTD., Japan), optical biometry (NIDEK AL-Scan, NIDEK CO., LTD., Japan) and corneal topography (Pentacam HR, Oculus, Wetzlar, optikgerate GmbH). The chord μ values of the patients were recorded before and after the operation. In order to prevent the measurements from being affected by pupil dilation, pre- and post-operative measurements were made in the same scotopic conditions before pupil dilation.

All surgical procedures were carried out by the same ophthalmologist (A.K) with standard phacoemulsification techniques. A transparent corneal incision was made with a 2.8 mm blade at 135 degrees, and auxiliary incisions were made at 0 and 180 degrees. In all patients included in the study, single piece hydrophobic IOL was placed in a capsule, and there were no complications during or after the operation. After the surgery, antibiotics (moxifloxacin 0.5%, QID) were administered for 1 week, steroid (dexamethasone 0.01%, QID at the beginning and tapered on a weekly basis) and artificial tear drops (hyaluronic acid 0.15%, QID) for 4 weeks.

Statistical Analysis

The collected data was evaluated with the IBM SPSS Statistics 21 package program. Kolmogrov-Smirnov test was applied for the normality of the population. Two independent samples t-test or Mann Whitney U test was used to examine the change between two independent groups. Wilcoxon test was used to calculate the difference between two dependent groups. Wilcoxon test was applied while examining the difference between the two dependent groups. Relationships between continuous variables were analyzed with the Pearson Chi-Square test. In all analyzes, the level of significance was taken as 0.05.

Ethical considerations

The study was conducted with the approval of the Clinical Research Ethics Committee of Karamanoglu Mehmetbey University (decision no: 06-2023/03) on 20.06.2023 in accordance with the Declaration of Helsinki. All participants were included in the study after obtaining informed consent forms.

RESULTS

Demographic data of the cases, changes in pre- and postoperative parameters are presented in tables 1 and 2. The data shows a statistically significant difference between the mean chord μ lenght before and after surgery. The postoperative mean chord μ length was significantly lower than the preoperative mean chord μ length (p=0.002). Similarly, the mean pupil size after phacoemulsification was significantly lower than the preoperative size (p=0.000). There was a weak positive correlation between the change in chord μ length and the change in pupil size, but this correlation was not statistically significant (p>0.05). There was no significant change in pre- and post-operative average keratometry values (p>0.05).

There was no significant difference in mean chord μ length between genders (p=0.361). A weak negative relationship between chord μ length and axial length was observed, but it was not statistically significant (p>0.05). Similarly, a weak positive relationship between chord μ length and preoperative anterior chamber depth was observed, but it was not statistically significant (p>0.05). No statistically significant relationship was found between any of the binary variables, including chord μ length and age (p>0.05).

Table 1. Frequency distribution regarding gender.

Gender	n	%
Male	18	54.5
Female	15	45.5
Total	33	100.0

Table 2. Descriptive statistics for continuous variables.

Variables	Min.	Max.	Mean	Std. Deviation
Preoperative Chord μ Lenght (mm)	0.05	1.04	0.39	0.24
Postoperative Chord μ Lenght (mm)	0.09	0.55	0.24	0.11
Preoperative Pupil Size (mm)	2.26	4.49	3.01	1.35
Postoperative Pupil Size (mm)	1.92	4.09	2.66	0.46
Axial Lenght (mm)	21.41	25.62	23.48	0.90
Anterior Chamber Depth (mm)	2.56	3.81	3.21	0.33
Age (years)	47.00	88.00	67.27	10.93
Preoparative Average Keratometry (diopters)	40.22	49.68	43.68	2.27
Postoperative Average Keratometry (diopters)	40.34	50.1	44.02	2.36

DISCUSSION

The study demonstrated a significant decrease in chord μ length after surgery. However, there was no statistically significant difference observed between chord μ length and pupil size, age, gender, anterior chamber depth, average keratometry and axial length. The results suggest that changes in the anterior chamber structures after phacoemulsification may influence the chord μ lenght.

In order to prevent decreased visual quality due to inappropriate centralization after corneal photoablation or IOL implantation, some clinical references like angle kappa, alpha or lambda, have been suggested (Arba Mosquera et al., 2015). It is noted that the terminology of kappa angle used in this context may cause inconsistencies in the literature and may be confused with lambda angle, which is predominantly referred to as the angle between the pupillary axis and the visual axis. The main reason for this is the assumption that both angles display close levels when the fixation point is distant (Moshirfar et al., 2013). On the other hand, angle kappa and chord mu can be considered as measuring the same clinical marker by different methods. A comparison between the preoperative and postoperative kappa angle revealed a significant alteration in the magnitude of the kappa angle during the postoperative examinations, alongside vector displacement post-surgery (Wang et al., 2020). Furthermore, post-surgery displacement of the pupil center away from the corneal center indicates that the kappa angle's ability to predict the success of mIOL implantation may not be dependable. One prominent reason for the shift in kappa angle is the possibility that the surgical procedure itself - likely due to exposure to ultrasonic energy and/or drug toxicity - can result in minor harm to the iris, ultimately leading to alterations in the shape, size, and location of the pupil. The shift in pupil center with changes in pupil size is an established fact (Yang et al., 2002). Additionally, the study reports a vector displacement in the corneal reflex relative to the corneal center before and after surgery, implying that the visual axis may undergo changes pre- and post-surgery. Since changes to the line of sight are possible, particularly in cortical or localized posterior subcapsular type cataracts, the clinical manifestation of the potential alteration in the visual axis pre- and post-phacoemulsification surgery is reflected in the alteration of the kappa angle.

The problem about the confusion about angle kappa among the ophthalmologists is the determination of the

visual axis and the pupil axis and the measurement of the angle between them. The visual axis, when a patient is fixating on a light source and viewing it coaxially, is very close to the location of the apparent first Purkinje-Sanson image. However, the pupil axis is the line drawn through the apparent centre of the pupil perpendicular to the corneal surface. The term apparent centre is used because it refers to the image of the pupil as seen through the cornea, which means that fixation must be moved nasally until the reflex is centred on the pupil and perpendicular to the cornea. The only clinical instrument that can measure this angle is the synoptophore, which is difficult to find. This is not the case with Scheimpflug tomography (i.e. Pentacam, Oculus). These instruments measure the actual distance from the axis to the actual pupil centre, which is smaller because it is not because it is not enlarged or shifted by the cornea. This distance would be referred to as the actual chord μ.

Chang and Waring recommended the use of this clinical indicator called chord μ to avoid misunderstandings that arose in earlier literature and to address discrepancies between various equipment configurations (Chang & Waring, 2014). Eyes with chord μ values >600 μm appear to be at greater risk for halo and glare complaints with diffractive multifocal IOLs (Holladay, 2019). Holladay et al. They reported the mean apparent chord μ value as 0.3 ± 0.15 mm and the upper limit of normal as 0.60 mm (mean ± 2.0 SD). The actual chord μ length was measured to be 0.2 ± 0.11 mm on average; thus, it can be seen that the upper limit of the real chord μ normal values is 0.42 mm. (Holladay, 2019). In our study, the apparent chord μ value was calculated as 0.39±0.24, which is close to the upper limit in Holladay's definition.

The most comprehensive cohort of chord μ length included 15,930 eyes of 8564 patients (Jiang et al., 2020). Chord μ length has been shown to increase linearly with age in both men and women. Multiple regression shows that chord μ increases with advanced age, male gender, and larger pupil size, but decreases inversely with axial length, keratometry, and anterior chamber depth.

In a study in which 8 patients underwent pinhole pupilloplasty, it was shown that the mean chord μ length was statistically significantly lower after surgery (Narang et al., 2019). It is stated that the correlation between the change in chord μ length and the change in mean pupil size is not significant. Although pupillary surgery was not performed in the patients in our study, similar results were obtained. Several studies investigating the change in pupil diameter after phacoemulsification have reported a statistically significant decrease in pupil diameter of 11-13% (Dick et al., 2005; Keuch & Bleckmann, 2002). Reasons for this change include the effect of increased anterior chamber volume after lens removal, replacement of the average 4.4mm lens with a much thinner IOL, and as a result of these anatomical changes, it has been suggested that the movement of the iris constrictor muscles may lead to a decrease in pupil diameter due to free movement and full capacity contraction of the iris muscles. However, this effect has been shown to be more pronounced in diabetic patients (Simsek & Toptan, 2023).

In a review of the studies on the change in chord-μ length after phacoemulsification surgery, Wang et al. (Wang et al., 2020) and Fernandez et al. (Fernández et al., 2018) reported that postoperative chord μ length decreased significantly, while Şener et al. (Şener et al., 2022) in a study conducted in our country, stated no significant change. In this study, however, it was shown that the chord μ length decreased significantly at the postoperative 3rd month. Two studies (Prakash et al., 2011; Karhanová et al., 2013) have shown that halos and glare are more likely to occur with diffractive multifocal IOLs when the apparent chord m is abnormally high (>0.60mm).

Limitations

Limitations of our study include its retrospective design. Secondly, because it did not include different types of cataracts, we have no data on the change in chord mu in cases other than nuclear cataract. It is well known that the recovery period after cataract surgery can last up to 6 months postoperatively and beyond. Due to the difficulties encountered during the data collection phase, the desired standardization could not be achieved.

CONCLUSION

Proper centralization is a necessity in both refractive operations and refractive IOL implantation to avoid the occurrence of high-grade aberrations and photic events. Therefore, it seems useful for surgeons to be familiar with chord μ measurements, especially regarding surgical preparation. Future studies with a larger patient population more standardized follow-up will be used to understand the predictive value of chord μ in both phacoemulsification surgery and corneal laser surgery.

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None

Conflict of Interest

The authors report no conflicts of interest to declare.

Author Contributions

Plan, design: AK, HT; **Material, methods, and data collection:** AK, HT; **Data analysis and comments:** AK, HT; **Writing and corrections:** AK, HT

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Ethical considerations

The study was conducted with the approval of the Clinical Research Ethics Committee of Karamanoglu Mehmetbey University (decision no: 06-2023/03) on 20.06.2023 in accordance with the Declaration of Helsinki. All participants were included in the study after obtaining informed consent forms.

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