Keratoconus and Cataract Surgery

Emine Esra Karaca[1], *Gokhan Celik*[2], *Ozlem Evren Kemer*[3]

ABSTRACT

Keratoconus, a progressive corneal disorder characterized by ectasia and thinning of the cornea, poses unique challenges in the context of cataract surgery. This review examines various strategies available for patients with keratoconus and cataracts, such as intraocular lens (IOL) calculation, selection and techniques for addressing astigmatism.

Keywords: Keratoconus, Cataract Surgery, Astigmatism.

INTRODUCTION

Keratoconus (KCN) is a bilateral noninflammatory progressive thinning of the cornea that results in irregular astigmatism and myopia.[1] Cataract surgery in subjects with keratoconus is challenging in all aspects. Firstly, preoperative assessment is crucial to prevent refractive errors. The situation and stage of keratoconus should be evaluated topographically. In addition, biometric evaluation (K values, axial length, formulations etc.) is important to choose intraocular lens (IOL). In non-ectatic eyes, biometry values can be precisely measured to determine the power of the implanted IOL. However, several factors affect the accuracy of the measurements in patients with keratoconus and impact IOL power calculations.[2,3] Secondly, intraoperatively determination of the main incision site and incision structure are very important for wound healing. As well as intraoperative determination of the main incision, anterior chamber visualization and capsulorhexis can be challenging under the surgical microscope predominantly in patients with scarring and severe irregular cornea. During the surgery, it is also important to attempt to minimize the intraocular pressure by modifying the phacoemulsification machine parameters to reduce stress on the cornea. In addition toric IOL stabilization is very important, in patients with keratoconus with a deep anterior chamber.[4] Thirdly, postoperative visual rehabilitation can be provided by using spectacles or contact lenses.

In this review, we will explore these two distinct yet related eye conditions - keratoconus and cataracts - preoperative evaluation, intraoperative evaluation and postoperative rehabilitation. We will explore the latest advancements in IOL selection for both conditions, highlighting the significant challenges and solutions for cataract patients with keratoconus.

PRE-OPERATIVE EVALUATION

Topographical Evaluation and Estimation of Corneal Power

Keratoconic corneas often exhibit marked asymmetry, making standard biometry less reliable. Topographical evaluation helps identify and quantify this asymmetry, allowing for customized IOL calculations. Various mathematical models and software tools are available to assist in these calculations.

Assessment of KCN degree, type and location of steepness, topographical pattern must be evaluated. Generally, Amsler-Krumeich Classification are used while determining of kerataconic degree. The degree of keratoconus is very important in determining the main incision site during surgery and deciding on a toric IOL (Table 1).[5]

Studies reveal that a key sources of error in calculating IOL power in patients with KCN arises from the incorrect

1- Assoc. Prof., University of Health Sciences Ankara Bilkent City Hospital, Department of Ophthalmology, Ankara, Türkiye

2- Ophthalmologist, Tarsus State Hospital, Department of Ophthalmology, Mersin, Türkiye

3- Prof., University of Health Sciences Ankara Bilkent City Hospital, Department of Ophthalmology, Ankara, Türkiye

Received: 30.10.2023
Accepted: 16.11.2023
J Glau-Cat 2023; 18: 139-144
DOİ: 10.37844/glau.cat.2023.18.21

Correspondence Address:
Emine Esra Karaca
University of Health Sciences, Ankara Bilkent City Hospital, Department of Ophthalmology, Ankara, Türkiye
Phone:
E-mail: dremineesra@gmail.com

Table1: *Standard Amsler-Krumeich Keratoconus Classification*	
Standard Amsler-Krumeich keratoconus classification.	
Stage I	Eccentric Steepening, Myopi/Astigmatism<5D, Mean K<48D
Stage II	Myopi/Astigmatism > 5D but<8D , Mean K<53 D, Absence of scarring, Minimal apical corneal thickness > 400 µm
Stage III	Myopi/Astigmatism > 8D but<10D , Mean K > 53 D, Absence of scarring, Minimal apical corneal thickness<400 µm but > 300 µm
Stage IV	Refraction not possible, Mean K > 55D, Central Corneal Scarring, Minimal apical corneal thickness<300 µm

measurement of corneal power.[4,6,7] Notably, the ratio between anterior and posterior corneal curvature changes in patients with KCN.[8,9] Therefore, classical keratometry which only takes into account the radius of the anterior curvature of the cornea and assumes a standard K index of 1.3375 based on the Gullstrand schematic eye model may not adequately account for the influence of the posterior cornea and can result in overestimation of corneal power in KCN patients.[6,9,10] Since, tear film irregularities are common in KCN, determining measurements of corneal curvature less repeatable.[10,11]

Modern elevation-based topography devices (such as the Pentacam) that demonstrate corneal sagittal curvature and front/back elevation maps may help reduce inaccurate corneal power measurement by taking the posterior curvature of the cornea into account (Figure 1).[12-14]

Wang et al.[13] showed that optical biometer-measured corneal powers were frequently higher than Pentacam measured corneal powers in patients with KCN. In another

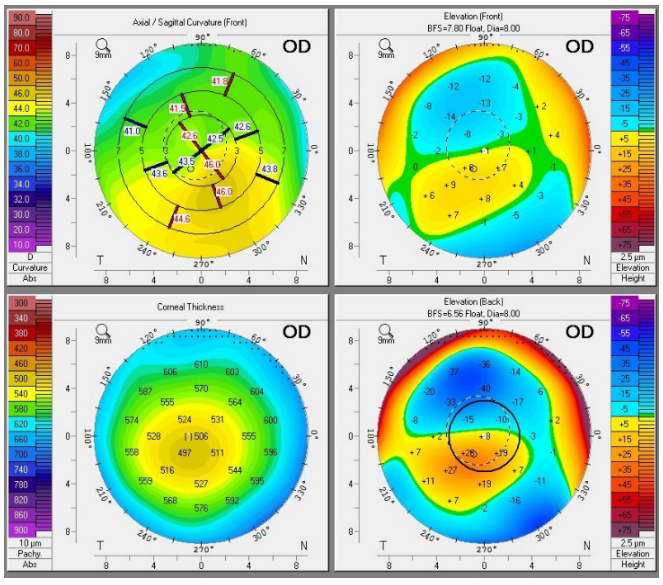

Figure 1: *Pre-operative topographic evaluation of keratoconic patients. Inferior steeping on sagittal curvature map and posterior elevation on back elevation map.*

study, Pentacam demonstrated superior repeatability for keratometry (K) measurements when maximum keratometry <55 diopters (D) compared with other technologies (i.e., topographer [EyeSys], slit scanning corneal topographer [Orbscan], partial coherence interferometry device [IOLMaster], and Javal manual keratometer) This study reported significant error and unreliability across all technologies in patients with K max >55 D.[7] Pentacam is able to calculate total corneal refractive power (TCRP) using ray tracing, which is believed to reflect true corneal power in keratoconic eyes more accurately. Kamiya et al.[15] reported that simulated K (simK), a measure calculated by using the standard K index and the radius of anterior corneal curvature, is generally higher than TCRP in KCN patients. Another study emphasizes that when we calculate IOL power using conventional keratometric readings, there is a need to optimize IOL power and that TCRP instead of Sim K may be useful in calculating IOL power, especially for advanced keratoconus.[16] Indeed, Equivalent K-Readings (EKR) are values provided by the Holladay Report and powered by the Pentacam (Oculus software). They are based on elevation topography maps. Equivalent K Readings correct keratometric values, focusing on the central cornea and balancing irregularities of the corneal curvature observed between steeper and flatter hemi-meridians.

The accuracy of keratometric values thus obtained to calculate pseudophakic IOL on keratoconic cornea is still under investigation, but the preliminary results obtained on patients with irregular astigmatisms are encouraging. For example, Figure 2 shows keratometric values obtained by the topography after EKR correction and is approximately half the value obtained using other means.

Intracorneal ring (ICR) may be recommended for severe keratoconic and highly astigmatic eyes. ICRs provide corneal stability, make more accurate corneal keratometric values, prevent postoperative refractive errors. Thus, the sequential order of intrastromal corneal rings implantation and cataract surgery can be considered as a treatment option in patients with severe keratoconus and cataract.[17,18]

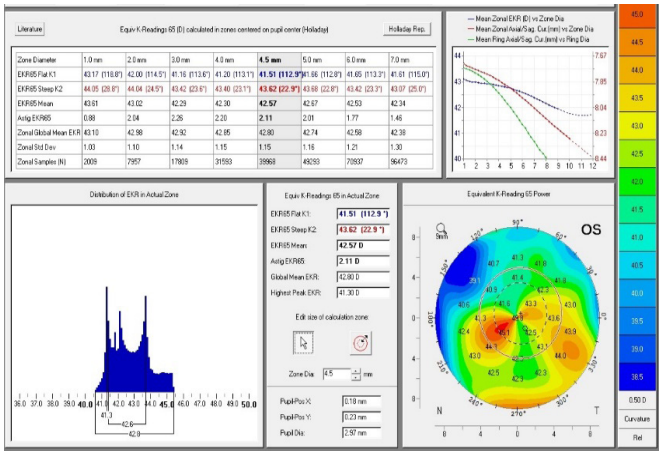

Figure 2: *Equivalent K-Readings obtained by Pentacam.*

Measurement of Axial Length

Measurement of axial length (AL) is another important issue when predicting IOL power in patients with keratoconic eyes. AL must measure with optical biometry devices rather than ultrasonography. KCN patients tend to have deeper anterior chambers and frequently exhibit longer axial lengths compared to non-keratoconic eyes.[19,20] The decentralization of the apex in patient with KCN compared to the normal cornea causes unreliability when measuring the visual axis.[21] Furthermore, the estimated lens position (ELP) is a key component in IOL power selection, which is calculated based on preoperative biometric values, mainly AL, anterior chamber depth and keratometry (Figure 3). Therefore, the ELP probably change in patient with keratoconus, IOL calculation result inaccurate measurements.[22]

Selection of IOL Power Formulation

There is no ideal formula for IOL power estimation in KCN patients. The conventional IOL formulas may cause hyperopic results, particularly when applied to patients with more advanced KC.[13,19,23] Earlier studies comparing the SRK, SRK II, and SRK/T formulas for IOL power estimation reported the better accuracy with the SRK II formula in eyes with mild KC, with no significant difference in accuracy between formulas in those with more advanced KCN.[6] A study by Savini et al.[19] reported that the SRK/T formula offered the better accuracy across all stages of KCN when compared with the Haigis, Hoffer Q,and Holladay I formulas. Another recent study by Wang et al. [24] reported that the Barrett Universal II formula performed best in mild and moderate KC compared with the SRK/T, Hoffer Q, Holladay I, Haigis, and Holladay II formulas. Barrett Universal II formula had the lowest median absolute error and the highest percentage of eyes within 0.5 D of predicted in stage I (52%) and stage II (50%) keratoconus, compared with the other formulas, which averaged 40% accuracy in stage I and 20% in stage II KCN [16] In a recent study by Kane et al. [23] , the Kane KCN formula performed better results than the SRK/T, Barrett Universal II, Holladay I, Holladay II, Haigis, Hoffer Q, and Holladay II formula in patients with all severities of KCN. The formula achieved ±0.5 D predictive accuracy in 60.7% of eyes with stage 1 KCN along with 43.2% and 24% in those with stage 2 and stage 3 disease, respectively. Kane et al.[23] suggested the implementation of a correction when using third generation IOL formulas depending on the KCN severity—for stage 1 (normal), stage 2 (0.75 to 1.5D), and stage 3 (2.00 to 3.00D).

KM ϕ2.4 mm	R1:	7.01 mm	48.15 D	147°
	R2:	6.81 mm	49.56 D	57°
	AVG:	6.91 mm	48.85 D	
	CYL:		- 1.41 D	147°
KM ϕ3.3 mm	R1:	7.04 mm	47.94 D	154°
	R2:	6.80 mm	49.63 D	64°
	AVG:	6.92 mm	48.79 D	
	CYL:		- 1.69 D	154°

Figure 3: *Keratometry results in a cataract patient with keratoconus by optical biometry device.*

Formulas that take into thought AL and other factors that help to estimate effective lens position (ELP), such as the Holladay 2, must be more proper. It is assumed that new ray-tracing formulas that assess TCRP, considering posterior corneal surface astigmatism, are going to provide to improve predictability in these irregular eyes even more in the future. However, recent studies have not demonstrated better outcomes using these formulas in nonkeratoconic eyes. [5,25,26] Larger series are needed to help elucidate which formula performs best.

Recently introduced KCN formulae through online calculators and newer methods to measure posterior corneal power such as total keratometry (TK) can help surgeons to achieve better refractive outcomes. The Barrett Universal 2 (BU2) KCN: measured posterior corneal astigmatism (PCA), which uses posterior corneal measurements, performed well in all subgroups and did not appear to require additional myopic targeting. For severe KCN eyes, KCN formulae should be adopted as preferred formulae; if TK values are unavailable, the BU2 KCN: predicted PCA was superior to SRK/T. For non severe KCN eyes, surgeons can also confidently use the EVO 2.0 formula with TK or K.[27]

IOL Options and Selection

The selection of monofocal lenses are recommended in patient with KCN. Monofocal toric lenses are the first choice, especially in patient with mild to moderate KCN and whose visual acuity is increased by glasses.[28,29] Patient selection for toric IOL implantation maintains the importance. In patients with relatively regular corneal astigmatism or with large degrees of astigmatism, toric IOLs may be discussed with the patient with the understanding of unpredictable refractive surprise and possible residual astigmatism. Manifest refractions that correspond with topographic and biometric measurements further inspire confidence in toric IOL selection.[30] Usually, toric lenses are not recommended in patient with severe degree KCN due to decreased predictability of refractive results. In addition, toric IOLs are not recommended if planning on use of RGP or scleral lens after surgery or patient with possibility of future keratoplasty.

Aspheric IOL are not recommended in patients with KCN. Normally cornea slightly prolate, but keratoconic cornea is highly prolate and Q value is severe negative. Hence, neutral or positive spheric IOL may be better options for KCN.[31]

Basically, multifocal IOLs are not recommended for patients with KCN. But recent studies reveal that multifocal IOL may be performed in patient with suspect or forme fruste KCN. In addition, some authors reported that phakic posterior chamber IOL may be a different option of refractive correction.[32]

The ethics of toric IOL implantation should be considered, as these lenses are not covered by insurance for patients in the United States. In our practice, we have found that some patients are willing to accept the uncertainty and are greatly appreciative of the improved UDVA achieved when reducing their astigmatism burden via the use of a toric IOL.[30]

Basically, when a cataract patient with keratoconus is applied to clinic, we have to evaluate all of situations. The first important evaluation is history of correct distance visual acuity (CDVA) or amount of increase in CDVA with spectacles. Especially if patients have history of good CDVA, monofocal (toric or non-toric) IOL are recommended. But if patients have history of poor CDVA, ICRS is recommended to ensure keratometric stabilization, after than toric IOL may be performed (Figure 4).

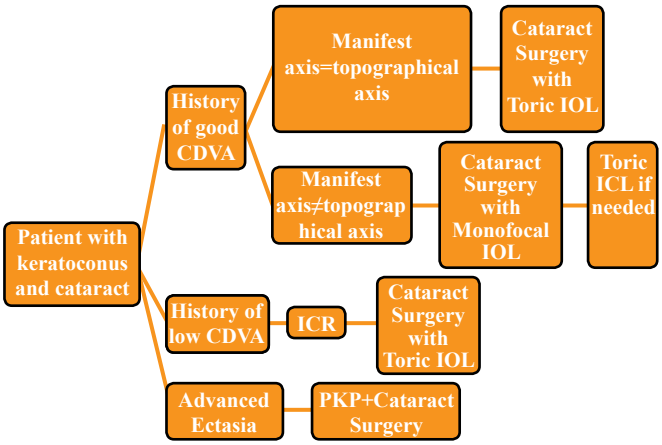

Figure 4: *Approach to a cataract patient with keratoconus*

INTRA OPERATIVE EVALUATION

Effects of corneal incision may not be anticipated precisely on K values and astigmatism in patients with KCN. When establishing incision locations, it's essential to take into account the thickness of the peripheral cornea. Especially severe peripheral thinning can result with leakage after surgery. In patients with an inferotemporal cone, a superotemporal incision must be performed, and if one apex is located superiorly, a temporal incision must be performed. Incisions must be performed near to limbus or sclera to reduce surgically induced astigmatism.[33,34]

Severe KCN can result light scattering due to corneal scarring and image distortion due to irregular corneal surface. To improve intraocular visibility and reduce image distortion due to the corneal irregularity it can be useful to spread a dispersive ophthalmic viscoelastic device such as the hydroxypropyl methylcellulose (HPMC) gel onto the cornea.[35]

IOL diameter can affect IOL intracapsular stability; an approximately 12-mm diameter may be large enough for IOL stability even in large capsular bags.[36] Moreover, the partially large capsular bag of keratoconic eye can cause to IOL rotation. In this situation capsular tension ring may be recommended. [19,20]

POST-OPERATIVE REHABILITATION

Post-operative visual rehabilitation can be ensured by using spectacles or contact lenses. Particularly RGP lenses are the most common lenses to correct refractive changing. In addition, scleral lenses may be used to correct refractive errors.[37]

CONCLUSION

In conclusion, cataract surgery in patients with keratoconus is a controversial topic in ophthalmology. Surgeons must evaluate preoperatively. In particular, the accurate estimation of corneal power and the selection of IOL calculation formulas are of great significance in preventing postoperative hypermetropia. Intraoperative and postoperative evaluation are highly important to prevent refractive errors. In addition timely cataract surgery in keratoconus patients can help preserve the corneal structure and minimize the risk of corneal scarring or hydrops, a potentially severe complication of keratoconus.

REFERENCES

1. Krachmer JH, Feder RS, Belin MW. Keratoconus and related noninflammatory corneal thinning disorders. Surv Ophthalmol. 1984;28:293-322.
2. Bozorg S, Pineda R. Cataract and keratoconus: minimizing complications in intraocular lens calculations. Semin Ophthalmol. 2014;29:376-9.
3. Ghiasian L, Abolfathzadeh N, Manafi N, et al. Intraocular lens power calculation in keratoconus; A review of literature. J Curr Ophthalmol. 2019;31:127-34.
4. Aiello F, Nasser Q, Nucci C, et al. Cataract Surgery in Patients with Keratoconus: Pearls and Pitfalls. Open Ophthalmol J. 2017;11:194-200.
5. Belin MW, Duncan J. Keratoconus: The ABCD Grading System Keratokonus: Das ABCD-System zur Stadieneinteilung. Published online 2016.
6. Thebpatiphat N, Hammersmith KM, Rapuano CJ, et al. Cataract surgery in keratoconus. Eye Contact Lens. 2007;33:244-6.
7. Hashemi H, Yekta A, Khabazkhoob M. Effect of keratoconus grades on repeatability of keratometry readings: Comparison of 5 devices. J Cataract Refract Surg. 2015;41:1065-72.
8. Edmund C. Posterior corneal curvature and its influence on corneal dioptric power. Acta Ophthalmol. 1994;72:715-20.
9. Camps V, Piñero D, Caravaca E, et al. Preliminary validation of an optimized algorithm for intraocular lens power calculation in keratoconus. Indian J Ophthalmol. 2017;65:690.
10. Watson MP, Anand S, Bhogal M, et al. Cataract surgery outcome in eyes with keratoconus. Br J Ophthalmol. 2014;98:361-364.
11. Mcmahon TT, Anderson RJ, Roberts C, et al. Repeatability of corneal topography measurement in keratoconus with the TMS-1. Optom Vis Sci. 2005;82:405-15.
12. Tamaoki A, Kojima T, Hasegawa A, et al. Intraocular lens power calculation in cases with posterior keratoconus. J Cataract Refract Surg. 2015;41:2190-5.
13. Wang KM, Jun AS, Ladas JG, Siddiqui AA, Woreta F, Srikumaran D. Accuracy of Intraocular Lens Formulas in Eyes With Keratoconus. Am J Ophthalmol. 2020;212:26-33.
14. Park DY, Lim DH, Chung TY, Chung ES. Intraocular lens power calculations in a patient with posterior keratoconus. Cornea. 2013;32:708-11.
15. Kamiya K, Kono Y, Takahashi M, Shoji N. Comparison of Simulated Keratometry and Total Refractive Power for Keratoconus According to the Stage of Amsler-Krumeich Classification. Scientific Reports 2018 8:1. 2018;8:1-5.
16. Wang KM, Jun AS, Ladas JG, Siddiqui AA, Woreta F, Srikumaran D. Accuracy of Intraocular Lens Formulas in Eyes With Keratoconus. Am J Ophthalmol. 2020;212:26-33.
17. Konda S, Ambati BK. Intracorneal ring segments followed by toric pseudoaccomodating IOL for treatment of patients with corneal ectasia and cataract. Am J Ophthalmol Case Rep. 2020;18:100693.
18. Lee SJ, Kwon HS, Koh IH. Sequential Intrastromal Corneal Ring Implantation and Cataract Surgery in a Severe Keratoconus Patient with Cataract. Korean J Ophthalmol. 2012;26:226.
19. Savini G, Abbate R, Hoffer KJ, et al. Intraocular lens power calculation in eyes with keratoconus. J Cataract Refract Surg. 2019;45:576-81.
20. Kovács I, Miháltz K, Németh J, et al. Anterior chamber characteristics of keratoconus assessed by rotating Scheimpflug imaging. J Cataract Refract Surg. 2010;36:1101-6.
21. Bourges JL. Cataract Surgery in Keratoconus with Irregular Astigmatism. Accessed June 2, 2023. www.intechopen.com
22. Alió JL, Peña-García P, Guliyeva FA, Soria FA, Zein G, Abu-Mustafa SK. MICS with toric intraocular lenses in keratoconus: outcomes and predictability analysis of postoperative refraction. Br J Ophthalmol. 2014;98:365-70.
23. Kane JX, Connell B, Yip H, et al. Accuracy of Intraocular Lens Power Formulas Modified for Patients with Keratoconus. Ophthalmology. 2020;127:1037-42.
24. Wang KM, Jun AS, Ladas JG, Siddiqui AA, Woreta F, Srikumaran D. Accuracy of Intraocular Lens Formulas in Eyes With Keratoconus. Am J Ophthalmol. 2020;212:26-33.
25. Leccisotti A. Refractive lens exchange in keratoconus. J Cataract Refract Surg. 2006;32:742-6.
26. Navas A, Suárez R. One-year follow-up of toric intraocular lens implantation in forme fruste keratoconus. J Cataract Refract Surg. 2009;35:2024-7.
27. Heath MT, Mulpuri L, Kimiagarov E, et al. Intraocular Lens Power Calculations in Keratoconus Eyes Comparing Keratometry, Total Keratometry, and Newer Formulae. Am J Ophthalmol. 2023;253:206-14.

28. Sauder G, Jonas JB. Treatment of keratoconus by toric foldable intraocular lenses. Eur J Ophthalmol. 2003;13:577-9.

29. Navas A, Suárez R. One-year follow-up of toric intraocular lens implantation in forme fruste keratoconus. J Cataract Refract Surg. 2009;35:2024-7.

30. Smith RG, Knezevic A, Garg S. Intraocular lens calculations in patients with keratoectatic disorders. Curr Opin Ophthalmol. 2020;31:284-7.

31. Moshirfar M, Walker BD, Birdsong OC. Cataract surgery in eyes with keratoconus: a review of the current literature. Curr Opin Ophthalmol. 2018;29:75-80.

32. Alfonso JF, Lisa C, Fernández-Vega L, et al. Intrastromal corneal ring segments and posterior chamber phakic intraocular lens implantation for keratoconus correction. J Cataract Refract Surg. 2011;37:706-13.

33. Aiello F, Nasser Q, Nucci C, et al. Cataract Surgery in Patients with Keratoconus: Pearls and Pitfalls. Open Ophthalmol J. 2017;11:194-200.

34. Hashemi H, Khabazkhoob M, Soroush S, et al. The location of incision in cataract surgery and its impact on induced astigmatism. Curr Opin Ophthalmol. 2016;27:58-64.

35. Chen YA, Hirnschall N, Findl O. Comparison of corneal wetting properties of viscous eye lubricant and balanced salt solution to maintain optical clarity during cataract surgery. J Cataract Refract Surg. 2011;37:1806-8.

36. Maedel S, Hirnschall N, Chen YA, et al. Rotational performance and corneal astigmatism correction during cataract surgery: aspheric toric intraocular lens versus aspheric nontoric intraocular lens with opposite clear corneal incision. J Cataract Refract Surg. 2014;40:1355-62.

37. Lo HL, Yeh SI, Cheng HC. Scleral contact lenses for visual rehabilitation in keratoconus andirregular astigmatism after refractive surgery. Taiwan J Ophthalmol. 2014;4:73-6.