• Clinical Research •

Relationship between objective and subjective refraction measurements in patients with mild keratoconus

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Abstract

● **AIM:** To compare objective dry retinoscopy and subjective refraction measurements in patients with mild keratoconus (KCN) and quantify any differences.

● **METHODS:** This cross-sectional study was done on 68 eyes of 68 patients diagnosed with mild KCN. Objective dry retinoscopy using autorefractometer and subjective refraction measurements were performed. Sphere, cylinder, J0, J45, and spherical equivalent values were compared between the two techniques.

● **RESULTS:** The mean age of 68 patients with mild KCN was 21.32±5.03y (12–35y). There were 37 (54.4%) males. Objective refraction yielded significantly more myopic sphere (-1.44 D *vs* -0.57 D), higher cylinder magnitude (-2.24 D *vs* -1.48 D), and more myopic spherical equivalent (-2.56 D *vs* -1.31 D) compared to subjective refraction (all $P<0.05$). The mean differences were -0.87 D for sphere, -0.76 D for cylinder, and -1.25 D for spherical equivalent. No significant differences were found for J0 and J45 values, indicating agreement in astigmatism axis ($P>0.05$).

● **CONCLUSION:** In patients with mild KCN, objective dry retinoscopy overestimates the degree of myopia and astigmatism compared to subjective refraction. The irregular cornea in KCN likely impacts objective measurements. Subjective refraction allows compensation for irregularity, providing a more accurate correction. When determining refractive targets, the tendency of objective methods to overcorrect should be considered.

● **KEYWORDS:** keratoconus; objective refraction; subjective refraction

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INTRODUCTION

Keratoconus (KCN) is an asymmetric bilateral, progressive and degenerative disease characterized by localized thinning and protrusion of the cornea, resulting in irregular astigmatism[1-3]. It leads to a qualitative and quantitative decline in vision, due to lower and higher-order aberrations generated by the deformation, and the possible occurrence of corneal opacities[4-6]. This deterioration in vision results in a reduced quality of life for these patients[7-8]. There are risk factors for developing KCN such as demographic and environmental factors[9].

Nowadays, refraction measurement by means of an auto-refractometer or retinoscopy is integrated into the examination procedure in many clinics and allows excellent guidance in the determination of refractive errors due to sufficiently high measurement accuracy[10-11].

Numerous studies confirmed this in comparison with subjective refraction[12-14]. One of the clinical characteristics of KCN would be the differences between the findings of objective and subjective refraction during the spectacle prescription for patients with KCN[15-17].

The marked differences between objective and subjective refraction measurements serve as a poignant reminder of the intricacies of managing refractive error in KCN patients. Furthermore, these patients exhibit more variability in manifest refraction[16,18]. As such, these findings advocate for meticulous and individualized care when addressing the visual needs of individuals grappling with KCN. With the progression of KCN, a notable and pronounced fluctuation in both uncorrected and best-corrected visual acuity (UDVA and BCVA) often manifests in patients at advanced stages of the disease[19-21].

In stark contrast, in patients exhibiting mild to moderate KCN, subjective refraction can yield more consistent data, potentially allowing for the enhancement of the patient's visual acuity to near-normal levels[22]. Nevertheless, it is crucial to acknowledge that the outcomes of objective and subjective refraction may deviate from one another[23].

However, there are few studies investigating the differences between these two important clinical measurements in mild KCN. A holistic understanding of the multifaceted challenges posed by KCN, including its dynamic nature and variable visual outcomes, is essential for providing optimal care to affected individuals.

Given the limited data on refractive measurement correlations in mild KCN, this study aimed to compare objective and subjective refraction findings in patients with mild KCN. The results will provide novel insights into managing refractive correction in this complex population.

PARTICIPANTS AND METHODS

Ethical Approval This cross-sectional study assembled its participant pool from individuals diagnosed with mild KCN, who had been referred to the cornea section of Farabi Eye Hospital in Tehran, Iran in 2023. The Tehran University of medical sciences' ethical committee approved the study, and all processes used adhered to the tenets of the Declaration of Helsinki and these tenets were followed during all phases of examinations. (Ethical code: IR.TUMS.FNM.REC.1402.107).

All participants in the study were identified as having mild KCN and necessitated a spectacle prescription to correct their refractive errors resulting from KCN. Specifically, individuals meeting the criteria for stage 1 KCN according to the Amsler-Krumeich classification were designated as members of the study group. Patients selected for examination and meeting the criteria for stage 1 KCN were chosen based on the previously outlined criteria detailed in the preceding section[24]. The characteristics of this stage are eccentric steepening, myopia and astigmatism less than 5 D, and mean central keratometry reading less than 48 D. Therefore, all patients with definite mild KCN were included in the study who are diagnosed through refraction data and corneal topography examinations and are under 40 years old[25]. As per the Amsler-Krumeich staging system, patients were categorized as having mild KCN (stage 1) if they met the following criteria: myopia or astigmatism less than 5.00 D, mean K less than 48.0 D, and evidence of eccentric steepening in their anterior corneal topography map[24]. It should be noted that all participants were instructed to discontinue the use of rigid contact lenses for a duration of 4wk and soft contact lenses for a period of 2wk prior to undergoing examination. Patients with the following conditions were excluded from the study: central corneal scar, herpetic keratitis, prior ophthalmic surgery, and any connective tissue disorders. Furthermore, individuals with KCN who had stages 2, 3, or 4 of the condition, as well as those diagnosed with other corneal ectatic disorders such as pellucid marginal degeneration and keratoglobus, were not included in the study's participant pool.

We collected a comprehensive set of examination data from patients diagnosed with mild KCN (stage 1). This data encompassed various aspects, including demographic characteristics, UDVA and corrected distance visual acuity (CDVA), spherical and cylindrical objective refractions measured using an auto-refractometer (Topcon RM-8000), and tomography parameters to diagnose and classify different stages of KCN were obtained through Pentacam HR (Oculus, Welzar Germany).

The examination process began with subjective refraction measurements and was followed by objective refraction data collection as the baseline. Subjective refraction was performed by the same optometrist starting from the objective refraction endpoint. Sphere, cylinder, and axis readings were refined to achieve maximum plus for the best CDVA. It should be mentioned that the image quality is very poor in irregular astigmatism. In order to rule out the exact end point, we used techniques like fogging (to eliminate accommodation), pinholes (to refine the spherical component), and stenopic slits (to refine the cylinder axis). The examiner then fine-tuned the spherical equivalent, spherical component, cylindrical refraction, and astigmatism axis to optimize the BCVA for each patient. All the resulting data were meticulously recorded in scoresheets and subsequently utilized for the statistical analyses.

Statistical Analysis SPSS 24 (IBM Inc., Chicago, USA) was performed for the statistical analyses. The mean±standard deviation (SD) and frequency values for each parameter obtained from objective and subjective refraction measurements encompassed spherical equivalent, spherical component, cylindrical component, and astigmatism axis were reported. Prior to conducting parametric analysis, the normal distribution of all the data was checked using the Shapiro-Wilk test. In cases where parametric analysis was appropriate, the paired *t*-test was utilized to compare the data from objective and subjective measurements. The Pearson correlation test was used to evaluate the correlation between objective and subjective refraction measurements. A significance level of $P<0.05$ was deemed statistically significant. J0 and J45 using vector analysis were calculated through the following equations: $J0=-(C/2)\times\cos(2\alpha)$ and $J45=-(C/2)\times\sin(2\alpha)$, where J0 represents the Jackson cross-cylinder power at axes 90° and

180°, and J45 represents the Jackson cross-cylinder power at axes 45° and 135°.

RESULTS

The mean age of 68 patients (68 eyes) with mild KCN was 21.32±5.03y (12–35y). There were 37 (54.4%) male patients and 31 (45.6%) female cases.

The mean±SD of the sphere, cylinder, J0, J45, and spherical equivalent in dry refraction was -1.44±1.20, -2.24±1.35, 0.04±0.96, 0.00±0.90, and -2.56±1.51 D, respectively. Also, the mean±SD of the sphere, cylinder, J0, J45, and spherical equivalent in subjective refraction was -0.57±0.84, -1.48±1.08, -0.06±0.64, 0.11±0.65, and -1.31±1.01 D, respectively. Table 1 showed descriptive statistics of objective and subjective refractive error components.

A comparison of objective and subjective refractive error components was reported in the Table 2. There were statistically significant differences between objective and subjective refraction for sphere, cylinder, and spherical equivalent (all $P<0.001$). The mean sphere was more myopic (negative) in objective refraction (-1.44±1.20 D) compared to subjective refraction (-0.57±0.84 D), with a mean difference of -0.87±0.98 D (95%CI -1.11 to -0.63). The mean cylinder was more negative (higher magnitude) in objective refraction (-2.24±1.35 D) versus subjective refraction (-1.48±1.08 D), with a mean difference of -0.76±0.97 D (95%CI -0.99 to -0.52). The mean spherical equivalent was more myopic in objective refraction (-2.56±1.51 D) compared to subjective refraction (-1.31±1.01 D), with a mean difference of -1.25±1.25 D (95%CI -1.55 to -0.94). There were no statistically significant differences between objective and subjective refraction for J0 and J45 (P=0.463, 0.361, respectively).

Scatter plots to compare mean values of objective and subjective spherical and cylindrical refractive error, J0, J45, and spherical equivalent is shown in Figure 1. A moderate positive correlation existed between objective and subjective spherical refractive error components. There was a strong positive correlation between objective and subjective measurements of cylindrical and spherical equivalent refractive error components.

DISCUSSION

The present proposed study investigated the objective and subjective refraction data and aims to compare the objective and subjective refraction measurements in patients with mild KCN. In the present study, we found that there were statistically significant differences between objective and subjective refraction for sphere, cylinder, and spherical equivalent. The mean sphere was more myopic (negative) in objective refraction compared to subjective refraction. Furthermore, the mean cylinder was more negative (higher magnitude) in objective refraction versus subjective refraction.

Table 1 Descriptive statistics of objective and subjective refractive error components

Parameters	*n*	Min	Max	Mean±SD
Objective refraction				
Sphere (D)	68	-4.50	1.25	-1.44±1.20
Cylinder (D)	68	-5.00	-2.00	-2.24±1.35
J0	68	-2.12	2.41	0.04±0.96
J45	68	-2.13	2.35	0.00±0.90
Spherical equivalent (D)	68	-6.50	0.13	-2.56±1.51
Subjective refraction				
Sphere (D)	68	-3.75	0.00	-0.57±0.84
Cylinder (D)	68	-4.00	0.00	-1.48±1.08
J0	68	-1.93	1.75	-0.06±0.64
J45	68	-1.92	1.80	0.11±0.65
Spherical equivalent (D)	68	-4.25	0.00	-1.31±1.01

J0: Jackson cross cylinder, axes at 0 and 90 degrees; J45: Jackson cross cylinder, axes at 45 and 135 degrees; D: Diopter; SD: Standard deviation.

Table 2 Comparison of objective and subjective refractive error components

Parameters	Mean±SD	MD±SD	95%CI of the difference		P^a
			Lower	Upper	
Sphere					
Objective	-1.44±1.20	-0.87±0.98	-1.11	-0.63	<0.001
Subjective	-0.57±0.84				
Cylinder					
Objective	-2.24±1.35	-0.76±0.97	-0.99	-0.52	<0.001
Subjective	-1.48±1.08				
J0					
Objective	0.04±0.96	0.10±1.07	-0.16	0.36	0.463
Subjective	-0.06±0.64				
J45					
Objective	0.00±0.90	-0.11±1.01	-0.36	0.13	0.361
Subjective	0.11±0.65				
Spherical equivalent					
Objective	-2.56±1.51	-1.25±1.25	-1.55	-0.94	<0.001
Subjective	-1.31±1.01				

J0: Jackson cross cylinder, axes at 0 and 90 degrees; J45: Jackson cross cylinder, axes at 45 and 135 degrees; SD: Standard deviation; CI: Confidence interval; MD: Mean difference. [a]Paired *t*-test. *P*-value less than 0.05 is statistically significant.

Also, the mean spherical equivalent was more myopic in objective refraction compared to subjective refraction. However, there were no statistically significant differences between objective and subjective refraction for J0 and J45. It is noteworthy that without considering the astigmatism axis, it is impossible to compare the numerical value of the cylinder simply. Thus, vector analysis components can be compared between the two techniques. In patients with mild KCN, objective refraction tends to overestimate myopia and astigmatism compared to subjective refraction. This study

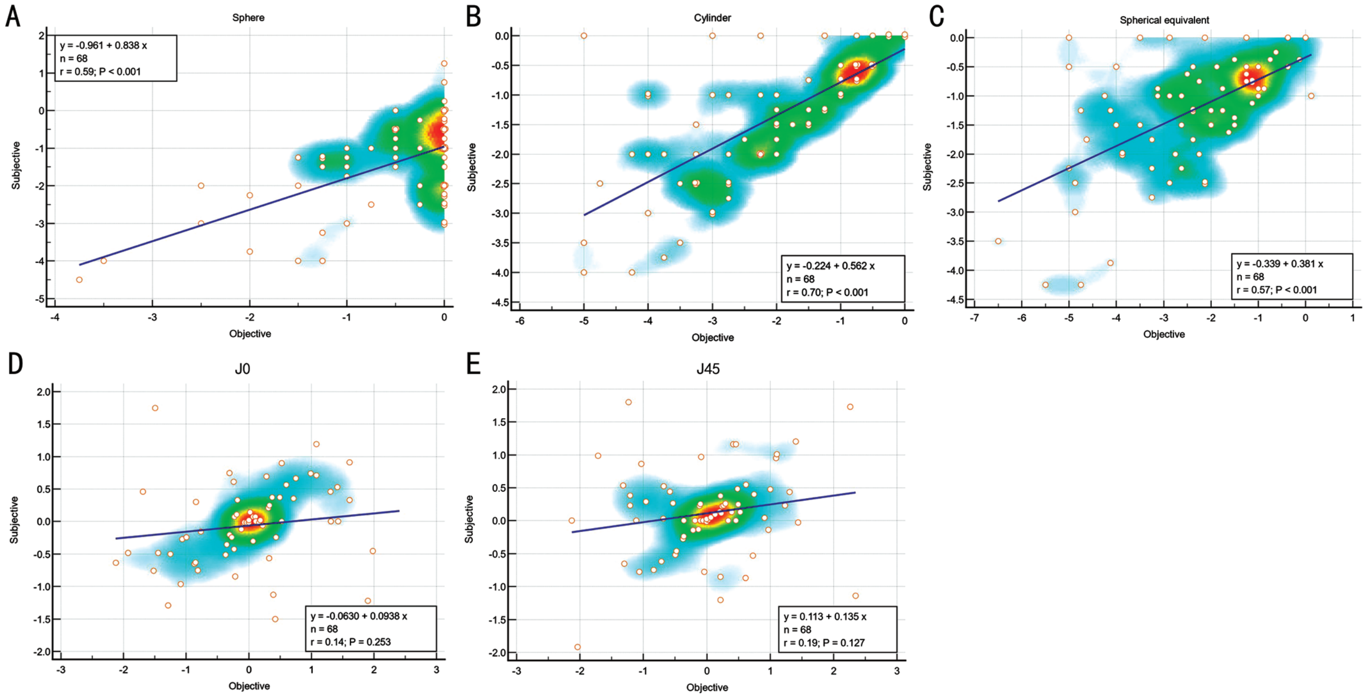

Figure 1 Scatter plots to compare mean values of objective and subjective sphere (A), cylinder (B), spherical equivalent (C), J0 (D), and J45 (E)
The solid blue line shows the regression line.

quantifies those differences, showing about 1 D more myopic sphere and 0.75 D more negative cylinder with objective versus subjective measurement. The lack of difference in J0 and J45 indicates agreement in the axis of astigmatism.

The severity of KCN also has a significant impact on visual and structural aspects, with more advanced stages of the disease leading to greater complications in both visual function and corneal anatomy[26-27].

Various structural and functional abnormalities have been identified in the corneas of individuals with KCN. The clinical manifestations of KCN depend on the stage and severity of the disease. In its early stages, often referred to as subclinical, form-fruste, or early KCN, there are typically no apparent clinical signs or symptoms in routine eye examinations. Instead, early signs can be detected through corneal topography or biomechanical evaluations[28]. Progression of KCN can lead to a range of visual issues, including myopia progression, irregular astigmatism, and in severe cases, corneal scarring[26,29]. Subjective refraction can be particularly challenging in KCN patients with moderate to advanced disease because their visual acuity can fluctuate significantly. Unlike normal eyes, where there is a clear endpoint for subjective refraction and stable visual acuity, KCN eyes present a greater challenge.

As a result, many eye care practitioners prefer to focus on improving and refining contact lens correction for KCN patients rather than relying solely on subjective refraction. It's worth noting that the initial Collaborative Longitudinal Evaluation of Keratoconus (CLEK) Study found that 58% of keratoconic eyes achieved visual acuity better than 20/40, and 75% achieved better than 20/60 with manifest refraction. However, this evaluation did not take into account the stability of refractive error and the limitations of visual acuity as a measure of overall visual function[30]. Another study from the CLEK group assessed the consistency of refraction in KCN patients[31]. The findings indicated that subjective refraction in KCN patients was reliable but not as consistent as in normal eyes.

Some prior studies similarly noted more negative objective spherical equivalent (SE) and cylinder values in KCN[15-32]. However, Pesudovs *et al*[13] found no difference in SE between techniques.

Soeters *et al*[16] compared visual performance using autorefraction and manifest refraction in KCN patients. They had different stages of KCN according to the Amsler-Krumeich criteria. Their results revealed that SE and spherical components of refractive error of autorefraction were more negative than those with manifest refraction. Moreover, they showed that the difference between subjective manifest refraction and autorefraction was increased where the cornea had been steepened.

Zareei *et al*[17] conducted a study to determine the agreement of astigmatism between an autorefractor and subjective manifest refraction. Moreover, they investigated which factors influence the difference between objective refraction and subjective refraction in these eyes. Their results showed maximum agreement of subjective refraction astigmatism with auto refractometer in patients with KCN. Consequently, they concluded that the result of autorefraction is the most appropriate starting point during subjective refraction in KCN patients. In this study, they enrolled patients with more severe KCN (stage 3, according to Amsler-Krumeich).

There are several possible reasons for the differences between autorefraction and manifest refraction measurements. The corneal protrusion in KCN decreases the image quality and creates a blur image at the retinal plane. These aberrations may interfere with the measurement because the autorefractor relies on image quality for its measurements. Continual progression alters patients' refractive state over time, affecting subjective precision[10,33].

In the context of the present study, it's important to note that our results have significant clinical implications for refractive correction in mild KCN patients. Eye care providers should consider the 0.75–1.00 D overestimation of myopia and astigmatism when using objective retinoscopy. The overestimation of myopia and astigmatism with objective retinoscopy is likely due to the irregular astigmatism caused by the abnormal corneal curvature in KCN. The distorted corneal surface may lead to inaccurate objective lens measurements. In contrast, subjective refraction allows the patient to correct for some of the irregular astigmatism by selecting the clearest vision on the phoropter. We found no significant difference between objective and subjective measurements of J0 and J45, indicating agreement regarding the axis of astigmatism. This suggests the increased magnitude of cylinder in objective refraction was not due to a shift in axis. Emphasizing subjective refraction allows patients to achieve optimal visual acuity. Further research is needed to determine whether these refractive differences have an impact on visual outcomes with different correction modalities.

Our study was performed in line with the standard practice commonly used by practitioners in clinical settings. This approach enabled us to establish a more practical and relevant comparison between objective and subjective refraction methods that ophthalmologists and optometrists can routinely implement.

The present study had several limitations. First, as a cross-sectional study, it provides only a one-time snapshot of refractive measurements. A longitudinal study would allow assessment of changes over time. Second, there was no control group of normal eyes without KCN for comparison. Comparing to refraction in normal corneas could highlight disease-specific effects. Third, as patients had mild KCN, the results may not be generalizable to more severe disease. Additional studies could explore a wider spectrum of KCN severity. Fourth, potential confounding factors like age, gender, and ethnicity were not analyzed in detail. Additional analysis controlling for these factors could reveal more nuanced outcomes. Fifth, the study relied solely on refractive data. The amount of higher-order aberrations, the functional basis of different autorefractometer systems, and the pupil diameter are important in the obtained results. The results of your study cannot be generalized to all patients with KCN. Incorporating topographic and aberrometric data could provide further insights into optical changes underlying the refractive differences.

In summary, due to the adverse effect of KCN on the vision-related quality of life of these patients, it is important to accurately determine their refractive error. In patients especially with mild KCN, prescription of accurate spectacles is one of the first and most cost-effective ways to provide optimal vision for them. Our study highlights the importance of prioritizing subjective refraction in the clinical decision-making process for these patients. Relying solely on objective measurements may lead to overcorrection of myopia and astigmatism, resulting in suboptimal visual outcomes. Furthermore, refraction is the first step for another protocol which includes topography or aberrometric studies. The next steps could involve incorporating topography and aberrometry data to further investigate the relationship between corneal irregularity and refractive outcomes. This study serves as a foundation for future protocols exploring the integration of advanced imaging techniques in the refractive management of KCN patients. By refining our understanding of the factors influencing refraction in KCN, we can develop more personalized treatment strategies to optimize visual outcomes and patient satisfaction.

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