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Original Article

Vision-related quality of life in Polish patients with keratoconus: A cross-sectional study using the KORQ questionnaire

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ABSTRACT

Purpose: To evaluate the impact of keratoconus on visual quality and quality of life among Polish patients by integrating subjective assessments using the Keratoconus Outcomes Research Questionnaire (KORQ) with objective clinical measurements.

Methods: A total of 100 patients (80% men, 20% women; median age: 39 years) with clinically diagnosed keratoconus completed the locally validated Polish version of the KORQ, including two subscales: Activity Limitation (18 items) and Symptoms (9 items). Objective data collected included best-corrected visual acuity (BCVA), corneal topography, pachymetry, and higher-order aberrations (HOA). Statistical analyses included biweight midcorrelations and robust linear regression models adjusted for age and gender.

Results: The mean Activity Limitation score was 51.53 (SD = 17.19) and the Symptoms score was 55.60 (SD = 16.14), indicating moderate functional impairment and symptom burden. The most challenging activities were night driving (mean = 2.06), seeing small distant objects (mean = 2.09), and coping with poor lighting (mean = 2.05). The most bothersome symptoms were distorted vision (mean = 1.84), sensitivity to smoke (mean = 2.05), and dusty environments (mean = 2.01). Higher-order aberrations, especially in the worse-seeing eye, showed the strongest associations with KORQ scores across both subscales (e.g., for Symptom subscale: HOA: $\beta = 2.84$; $p = 0.004$; vertical coma: $\beta = 5.83$; $p = 0.019$), while BCVA in the better-seeing eye was significantly associated with both lower symptom burden ($\beta = -9.83$; $p = 0.047$) and functional limitation ($\beta = -12.13$; $p = 0.042$). Traditional structural parameters, such as Kmax and corneal thickness, showed no significant predictive value.

Conclusions: Keratoconus significantly impairs visual functioning and causes a high symptom burden among Polish patients. Best-corrected visual acuity and higher-order aberrations, especially in the worse-seeing eye, are the strongest predictors of reduced vision-related quality of life. These findings emphasize the need to focus clinical management on improving optical quality, rather than solely correcting structural corneal features.

Introduction

Keratoconus is a progressive, degenerative disorder of the cornea that significantly impairs visual function and reduces the quality of life for affected individuals.[1] The characteristic corneal irregularities associated with this condition lead to refractive errors, decreased visual acuity, heightened light sensitivity, and other visual disturbances, which profoundly affect patients' daily activities and psychological well-being.[2]

Conventional clinical parameters such as Kmax, corneal thickness, or astigmatism do not always reflect patients' subjective visual experience. Therefore, increasing attention has been given to assessing visual quality from the patient's perspective using standardized questionnaires that quantify the impact of keratoconus on everyday visual functioning. One of the instruments designed for this purpose is the Keratoconus Outcomes Research Questionnaire (KORQ). This tool validated instrument developed by Khadka et al.[3] to assess the impact of keratoconus on patients' vision-related quality of life. It specifically addresses activity limitations and symptom severity, considering the unique visual impairments associated with the condition. The original version consists of 29 items, divided into two subscales: the Activity Limitation subscale (18 items) and the Symptom subscale (11 items). Responses are recorded using a four-point Likert scale, with an additional "not applicable" option. The questionnaire is being progressively validated across an increasing number of countries worldwide.[4–7,35] It functions as a standardized instrument for assessing visual quality and monitoring changes, particularly following interventions such as corneal crosslinking.[8–9] The KORQ was successfully validated for the Polish context.[10]This study aimed to evaluate the impact of keratoconus on visual quality by integrating clinical measurements with

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subjective patient-reported outcomes, utilizing the Keratoconus Outcomes Research Questionnaire (KORQ).Previous studies on this topic, including those by Tan et al,[11] Gothwal et al,[12] Pinto et al,[13] consistently show that poorer best-corrected visual acuity (BCVA) and greater disease severity are associated with worse quality-of-life scores. However, these studies primarily focused on visual acuity and corneal topography, with little or no attention to higher-order aberrations (HOA). Gothwal et al.[12] reported only a weak correlation between total HOA RMS and KORQ outcomes, without examining individual aberration components. Similarly, Schümmer et al.[14] demonstrated that increased coma and total HOA were associated with poorer visual-functioning scores, but their study used a general visual-functioning questionnaire rather than the keratoconus-specific KORQ.

Despite the growing number of studies assessing quality of life in keratoconus, several important gaps remain. Previous KORQ-based research has primarily focused on visual acuity and corneal topography, whereas only one study included aberrometric data, and even then, only total HOA RMS was analyzed without examining individual aberration components. Moreover, most studies averaged results between both eyes, overlooking the functional asymmetry characteristic of keratoconus, where the better-seeing eye often dominates visual performance. No research to date has investigated the relationship between specific higher-order aberrations and KORQ outcomes, particularly in a Central European population. Finally, prior analyses relied mainly on simple correlation methods, without considering the complex, potentially non-linear relationships between optical parameters and self-reported visual functioning. Despite extensive research on the vision-related quality of life in keratoconus patients, there is a noticeable lack of such studies within the Polish population, underscoring the need for localized research in this area. Upon further exploration, we identified a notable limitation in the availability of validated instruments for evaluating visual quality in this patient population.[15]

Combining objective clinical measurements such as higher-order aberrations (HOA), corneal topographic parameters (e.g., Kmax, pachymetry), and visual acuity with subjective patient-reported outcomes from the KORQ questionnaire, this study identifies key predictors of visual disability and symptom burden in keratoconus. The findings provide a comprehensive evaluation of how corneal irregularities, optical distortions, and loss of visual acuity contribute to functional impairment, underscoring the importance of advanced optical corrections and personalized treatment strategies to improve the quality of life for keratoconus patients. The analysis distinguished between the better- and worse-seeing eye and used advanced multivariable and non-linear statistical models to capture the complex relationships between visual function and quality-of-life outcomes. This comprehensive approach offers new insight into how optical irregularities and visual acuity contribute to perceived visual disability and may support more individualized strategies for improving patients' visual quality and well-being.

Materials and methods

This cross-sectional study with prospective data was conducted between July 2023 and November 2024 in the Department of Ophthalmology of the District Railway Hospital in Katowice, Poland. The Polish KORQ questionnaire was administered to 100 patients. The inclusion criteria for participation were as follows: adult men and women with a confirmed diagnosis of keratoconus at any stage and no other significant ophthalmic diseases. Patients who had undergone corneal transplantation in one eye were also included, if keratoconus had been diagnosed in the other eye as well. Each participant underwent a comprehensive ophthalmologic evaluation, accompanied by a detailed medical history interview. Information on the type of visual correction was collected for all participants. Patients who reported alternating between glasses and contact lenses were instructed to complete the KORQ based on their most frequently used form of correction.

Uncorrected visual acuity (UVA) and best-corrected visual acuity (BCVA) for each eye was measured monocularly using the Early Treatment Diabetic Retinopathy Study (ETDRS) chart (Precision Vision, La Salle, IL, USA) under standardized photopic conditions. The results were recorded in decimal notation. All measurements were performed by the same experienced examiner to ensure consistency. The stage of keratoconus was determined using the Amsler−Krumeich classification. Topographic (Kmax, astigmatism), pachymetric (CCT, MCT). and Higher-order aberrations (HOA) were derived from Scheimpflug-based corneal topography using the Pentacam HR system (Oculus, Germany). All measurements were performed under standard mesopic conditions with proper fixation, and image quality was verified according to the manufacturer's guidelines. Aberrometric parameters were analyzed for a standardized 6.0-mm pupil diameter. Additionally, an effort was made to identify other factors influencing vision quality by incorporating a range of clinical parameters such as Total uncorrected visual acuity (Total UVA) was defined as the sum of uncorrected visual acuity values for the better- and worse-seeing eyes, and Total best-corrected visual acuity (Total BCVA) as the sum of best-corrected visual acuity in both eyes. BCVA asymmetry was calculated as the difference between BCVA in the better- and worse-seeing eyes, reflecting interocular disparity in visual performance. The thickness gradient (TG) represented the absolute difference between central corneal thickness (CCT) and minimum corneal thickness (MCT), providing an estimate of corneal thinning severity. The better-seeing eye was defined as the eye with higher BCVA

For statistical analysis, data were stratified by the better-seeing and worse-seeing eye. This division was necessary due to the high asymmetry of keratoconus, where one eye often exhibits significantly more advanced disease than the other. The better-seeing eye predominantly determines overall visual function and practical performance in daily life, while the worse-seeing eye plays a key role in binocular vision, contrast sensitivity, and visual discomfort due to aberrations. Analyzing both eyes together could obscure these distinct functional contributions and lead to misleading conclusions about the impact of keratoconus on quality of life. By evaluating them separately, it was possible to more accurately determine which clinical parameters best predict functional limitations versus symptom severity, allowing for a more precise understanding of the disease's real-world consequences.

Statistical analysis

Statistical analyses were performed with a significance level set at $\alpha = 0.05$. The normality of continuous variables' distributions was evaluated using the Shapiro-Wilk test.[16] The method of data presentation (mean ± SD for normally distributed variables and median with interquartile range for non-normally distributed variables) was already specified in the footnotes below the relevant tables. Continuous variables that did not conform to a normal distribution were summarized using medians and interquartile ranges (*IQRs*), defined as the difference between the first and third quartiles. For ordinal variables, such as questionnaire scores from the Keratoconus Outcomes Research Questionnaire (KORQ), means and standard deviations were reported as measures of central tendency and variability, respectively. Categorical variables were described using absolute frequencies (*n*) and corresponding percentages (%).

Differences in numerical variables between two independent groups were assessed using the Wilcoxon rank-sum test for non-normally distributed data.[17] To explore relationships between the total domain scales of the KORQ and numeric clinical parameters, biweight mid correlation coefficients − a robust alternative to traditional similarity metrics were computed.[18] For the analysis of the effects of numeric clinical parameters on the total domain scales of the KORQ, robust linear regression (RLM) was employed to estimate regression coefficients, with adjustments for age and gender as covariates.

Estimating person scores on the logit scale using the rating scale model

The KORQ responses were analyzed using Rasch modeling to convert ordinal questionnaire data into linear interval measures representing the underlying constructs of visual functioning and symptoms.[19] This approach ensures that each unit change in the score reflects an equal change in perceived visual ability, addressing the non-linearity and unequal weighting of items inherent to raw Likert-type sums.

Rasch analysis also evaluates item fit, targeting, and measurement precision, producing person and item reliability indices comparable to traditional internal consistency measures. These features enable valid parametric statistical analyses and facilitate meaningful comparisons between individuals and subscales.

Person scores for the KORQ symptoms and visual functioning subscales were estimated using a rating scale approach within the Rasch measurement framework.[20–21] Details regarding model assumptions and parameter estimation are provided in the Supplementary Material.

Rescaling of person logit scores to a 0–100% scale

Person logit scores for both analyzed domains were linearly rescaled to a 0–100% scale to facilitate clinical interpretation. This rescaling employed a linear transformation based on the theoretical range of logit scores, determined experimentally to reflect the full spectrum of symptom severity.[22] The theoretical minimum corresponded to the lowest response category (0) across all items, and the maximum to the highest category (3), representing minimal and maximal symptom severity, respectively.[23]

On the rescaled scale, higher values indicate worse visual functioning or greater symptoms. This transformation preserves the measurement properties of the Rasch model, allowing standardized interpretation and comparison of results across patients and studies.[24] Details of the rescaling procedure are provided in the Supplementary Material.

Rescaled person-level scores for both subscales, along with group comparisons and regression results based on these scores, are presented in Appendix Tables 1–4.

Statistical tool

Analyses were conducted using the R Statistical language[25] on Windows 11 Pro 64 bit (build 26100), using the packages rio (version 1.2.1)[26], sjPlot (version 2.8.15)[27], eRm[28], report[29], gtsummary[30], MASS (version 7.3.60.0.1)[31], and dplyr.[32]

Results

Patient characteristics and quality of life outcomes in patients with keratoconus

Table 1 summarizes the baseline demographic and clinical characteristics of the 100 patients included in the study. The cohort consisted predominantly of men (80%), with a median age of 39 years. The median age at diagnosis was 29 years, indicating that most participants had lived with the disease for several years before evaluation.

Most patients presented with moderate disease severity and bilateral involvement. As expected for a tertiary referral cohort, visual and corneal parameters demonstrated considerable variability, encompassing a wide range of keratoconus stages. Visual acuity and refractive data reflected significant impairment, while corneal topography revealed increased curvature, reduced corneal thickness, and marked asymmetry between eyes. Aberrometric analysis, performed in a subset of patients, showed pronounced higher-order aberrations in the worse-seeing eye, consistent with advanced structural changes.

Overall, the data highlight the heterogeneity and severity of keratoconus in this clinical population, underscoring both functional and morphological deterioration. To improve readability, Table 1 presents only the key demographic and clinical variables, while the full dataset, including detailed visual, topographic, and aberrometric parameters, is available in Table A5 in the Appendix. Values are presented as n (%) for categorical variables and as median (interquartile range, IQR) for continuous variables.

Table 1
Baseline demographic and clinical characteristics of patients with keratoconus (*N* = 100).

Characteristic	*n*	*Value*
Demographics		
Gender:	100	
Female		20 (20.00%)
Male		80 (80.00%)
Age (years)	100	39.0 (30.00, 51.00)
Age at diagnosis (years):	100	29.0 (20.0, 35.25)
Treatment for keratoconus		
Keratoplasty	100	37 (37.00%)
CXL	100	20 (20.00%)
Any treatment	100	55 (55.00%)
Correction Type		
Glasses	100	42 (42.00%)
Contact Lenses	100	30 (30.00%)
Any correction	100	33 (33.00%)
Keratoconus Severity		
Stage of Keratoconus, better eye:	69	
I		17 (24.64%)
II		18 (26.08%)
III		16 (23.19%)
IV		18 (26.08%)
Stage of Keratoconus, worse eye:	85	
I		12 (14.12%)
II		18 (21.18%)
III		27 (31.76%)
IV		28 (32.94%)
Refractive and Visual Acuity data		
Astigmatism [D], better eye	100	2.63 (1.49, 3.98)
Astigmatism [D], worse eye	100	4.00 (2.58, 6.31)
UVA better eye	100	0.31 (0.16, 0.60)
UVA, worse eye	100	0.08 (0.05, 0.20)
BCVA, better eye	100	0.63 (0.42, 1.00)
BCVA, worse eye	100	0.20 (0.08, 0.50)
Kmax better eye [D]	100	47.20 (44.80, 51.85)
Kmax worse eye [D]	100	51.65 (47.03, 58.13)
CCT better eye [µm]	100	489.50 (462.75, 525.25)
CCT worse eye [µm]	100	466.00 (435.75, 502.25)
MCT better eye [µm]	100	472.50 (428.25, 514.25)
MCT worse eye [µm]	100	433.50 (368.50, 473.25)
		2.1

Footnotes: *N* = total cohort size; *n* = number of participants with available data for each characteristic. Values are presented as n (%) for categorical variables and median (interquartile range, *IQR*) for continuous variables. D = dioptres; µm = micrometers; VIScc = visual acuity composite score; OP = right eye; OL = left eye. Aberration measurements were available for a subset of patients due to equipment limitations. Data are presented as mean ± SD or median (IQR), depending on variable distribution.

Impact of keratoconus on daily activities: results from the KORQ activity limitation scale

Table 2 presents the mean scores for the Activity Limitation domain of the Keratoconus Outcomes Research Questionnaire (KORQ) in the study group (N = 100). Each question assesses the extent to which visual impairment from keratoconus interferes with specific daily activities, with responses scored from 0 (no difficulty) to 3 (severe difficulty). The overall Activity Limitation Scale ranges from 0 to 100, with higher scores indicating greater limitations. Values are presented as mean ± standard deviation. Patients reported the greatest difficulty with activities requiring precise distance vision or adaptation to varying lighting conditions. Specifically, tasks such as seeing small objects in the distance (Q17, mean: 2.09), general distance vision (Q9, mean: 2.06), driving at night (Q3, mean: 2.06), glare from oncoming headlights (Q10, mean: 2.06), and seeing in poor lighting conditions (Q14, mean: 2.05) had the highest mean difficulty ratings, indicating a moderate to severe impact on quality of life.

Table 2
Mean scores for the activity limitation domain of the keratoconus outcomes research questionnaire (KORQ) in patients with keratoconus ($N = 100$).

Characteristic	*n*	*Mean (SD)*
Activity Limitation Domain (KORQ)		
Q1: How much does your vision interfere with using a computer screen?	100	1.80 (0.96)
Q2: How much does your vision interfere with driving during the day?	100	1.50 (1.08)
Q3: How much does your vision interfere with driving during the night?	100	2.06 (1.08)
Q4: How much does your vision interfere with reading street signs?	100	1.46 (1.01)
Q5: How much does your vision interfere with watching TV?	100	1.41 (0.87)
Q6: How much does your vision interfere with walking up/down steps?	100	0.93 (0.89)
Q7:. How much does your vision interfere with avoiding objects in your path?	100	0.88 (0.91)
Q8: How much does your vision interfere with your ability to do your job?	100	1.45 (1.01)
Q9: How much does your vision interfere with seeing in the distance?	100	2.06 (0.86)
Q10: How much do on coming lights interfere with your ability to see, to do your tasks?	100	2.06 (0.89)
Q11: How much does your vision interfere with doing fine tasks near?	100	1.77 (0.99)
Q12: How much does your vision interfere with doing your hobby?	100	1.34 (0.99)
Q13: How much does your vision interfere with recognizing faces?	100	1.57 (0.93)
Q14: How much does your vision interfere with seeing in poor light?	100	2.05 (0.78)
Q15: How much does your vision interfere with doing household tasks? (e.g., cleaning, ironing, washing, washing up)	100	1.05 (0.91)
Q16: How much does your vision interfere with judging depth?	100	1.59 (1.00)
Q17: How much does your vision interfere with seeing small objects in the distance? (e.g., golf ball, darts)	100	2.09 (0.85)
Q18: How much does your vision interfere with sighting tasks? (e.g., camera, microscope, binoculars, etc.)	100	1.55 (1.01)
Summary Score		
Activity Limitation Scale Score (0−100)	100	51.53 (17.19)

Footnotes: N = total cohort size; KORQ = Keratoconus Outcomes Research Questionnaire; scores for individual items range from 0 (no difficulty) to 3 (severe difficulty), and the Activity Limitation Scale Score ranges from 0 −100, with higher scores indicating greater limitation. Values are presented as mean ± standard deviation.

Moderate difficulty was reported for activities involving computer screen use (Q1, mean: 1.80), fine tasks at close range (Q11, mean: 1.77), recognizing faces (Q13, mean: 1.57), and performing sight-related tasks such as using binoculars or a camera (Q18, mean: 1.55). Daytime driving (Q2, mean: 1.50) and job-related visual tasks (Q8, mean: 1.45) also posed significant challenges, albeit to a slightly lesser extent.

Tasks associated with relatively lower difficulty included engaging in hobbies (Q12, mean: 1.34), watching television (Q5, mean: 1.41), judging depth (Q16, mean: 1.59), walking up or down stairs (Q6, mean: 0.93), avoiding obstacles (Q7, mean: 0.88), and performing routine household chores such as cleaning or ironing (Q15, mean: 1.05). These activities generally require broader visual function rather than precise or detailed vision.

The mean Activity Limitation Scale score for the entire cohort was 51.53 (standard deviation: 17.19), indicating that, on average, patients experienced moderate functional limitations due to visual impairment across daily activities.

Overall, these findings demonstrate that keratoconus has the greatest impact on activities that require detailed distance vision, precise visual discrimination, and the ability to adapt to challenging lighting conditions. In contrast, general mobility and routine household tasks were comparatively less affected by the visual impairments associated with keratoconus.

Table 3
Mean scores for Symptoms Scale of the keratoconus outcomes research questionnaire (KORQ) in patients with keratoconus ($n = 100$).

Characteristic	*N*	*Mean (SD)*
Symptoms Domain (KORQ)		
Q1: How much are you troubled by distorted vision?	100	1.84 (0.96)
Q2: How much are you troubled by glare and wearing sunglasses all the time?	100	1.39 (1.12)
Q3: How much does a bright sunny day interfere with your ability to see, to do your tasks?	100	1.53 (1.10)
Q6: How much are you troubled by dry eyes?	100	1.53 (0.97)
Q7: How much are you troubled by windy days?	100	1.43 (1.03)
Q8: How much are you troubled when you are tired?	100	1.55 (0.85)
Q9: How much are you troubled by dry days?	100	1.56 (0.98)
Q10: How much are you troubled by dusty days?	100	2.01 (0.94)
Q11: How much are you troubled by smoky environments?	100	2.05 (0.86)
Summary Score		
Symptom Scale Score (0−100)	100	55.60 (16.14)

Footnotes: N = total cohort size; KORQ = Keratoconus Outcomes Research Questionnaire; scores for individual items range from 0 (none) to 3 (severe), and the symptom scale score ranges from 0−100, with higher scores indicating greater symptom severity. Values are presented as mean ± standard deviation.

Tables 2 and 3 present raw mean item scores (0−3) for each KORQ question, together with Rasch-transformed and linearly rescaled total scores (0−100) for each subscale. Raw scores reflect the ordinal responses provided by participants, while the Rasch-rescaled scores provide interval-level measures that allow valid statistical comparison and easier clinical interpretation.

Impact of keratoconus on visual symptoms: results from the KORQ symptoms scale

Table 3 presents the mean scores for the Symptoms domain of the Keratoconus Outcomes Research Questionnaire (KORQ) in a group of 100 patients. Each item assesses the extent to which various visual symptoms affect patients, rated on a scale from 0 (no trouble) to 3 (severe trouble). The overall Symptoms Scale score ranges from 0 to 100, with higher scores indicating greater symptom severity. Values are presented as mean ± standard deviation.

Patients reported the most significant difficulties with environmental irritants and visual disturbances, particularly those related to challenging external conditions. The most severe symptoms included trouble caused by smoky environments (Q11; mean: 2.05), dusty days (Q10; mean: 2.01), distorted vision (Q1; mean: 1.84), difficulties on dry days (Q9; mean: 1.56), and trouble with vision when fatigued (Q8; mean: 1.55).

Moderate trouble was reported for symptoms such as vision interference on bright sunny days (Q3; mean: 1.53), dry eyes (Q6; mean: 1.53), problems caused by windy conditions (Q7; mean: 1.43), and glare sensitivity requiring frequent use of sunglasses (Q2; mean: 1.39).

These findings highlight that keratoconus patients primarily experience discomfort and visual impairment due to environmental factors (e.g., smoke, dust) and visual distortion. Additionally, symptoms related to fatigue, dryness, bright sunlight, and glare sensitivity significantly contribute to their daily functional difficulties. Overall, the results indicate a substantial symptom burden among patients with keratoconus, particularly exacerbated by external environmental triggers.

Analysis of the impact of demographic and clinical factors on subjective quality of life (Table 4)

Table 4 presents a comparison of Keratoconus Outcomes Research Questionnaire (KORQ) Activity Limitation and Symptom Scale scores among keratoconus patients based on various clinical and demographic characteristics.

Table 4
Comparison of activity limitation and symptom scale scores across patient characteristics in patients with keratoconus ($N = 100$).

Characteristic	*Subgroup*	*N*	*N*	*Activity Limitation Scale Score (0–100)*	*Symptom Scale Score (0–100)*	*p-value*
Gender						
	Female	20	100	63.62 (52.35, 70.76)	64.49 (52.83, 72.43)	**0.003**
	Male	80		49.23 (38.74, 58.82)	53.32 (42.87, 63.37)	**0.009**
Keratoplasty						
	No	47	85	49.23 (41.16, 57.31)	53.32 (46.19, 63.37)	0.471
	Yes	38		52.07 (36.84, 64.64)	52.33 (41.08, 65.61)	0.674
CXL						
	No	65	85	49.23 (38.74, 59.74)	53.32 (42.87, 63.37)	0.293
	Yes	20		52.64 (46.67, 62.62)	55.28 (47.26, 66.21)	0.317
Any Treatment						
	No	45	100	50.36 (41.16, 61.00)	53.32 (47.26, 65.61)	0.920
	Yes	55		51.50 (37.47, 62.29)	55.28 (42.87, 65.61)	0.726
Correction Type: Glasses						
	No	58	100	52.07 (44.67, 62.29)	53.32 (47.26, 65.61)	0.259
	Yes	42		49.79 (36.53, 61.00)	55.28 (42.87, 65.61)	0.622
Correction Type: Contact Lenses						
	No	70	100	53.79 (41.16, 63.62)	55.28 (45.65, 67.42)	0.149
	Yes	30		49.23 (37.80, 56.72)	51.34 (43.43, 62.33)	0.182
Correction Type: No Correction						
	No	67	100	50.36 (38.74, 61.00)	53.32 (42.87, 65.61)	0.222
	Yes	33		53.79 (45.82, 63.62)	55.28 (49.33, 68.02)	0.131
Stage of Keratoconus, Better Eye						
	Small (1–2)	35		49.23 (38.72, 61.02)	53.32 (43.99, 61.30)	0.266
	Large (3–4)	34	69	52.64 (46.96, 62.96)	55.28 (49.33, 68.02)	0.193
Stage of Keratoconus, Worse Eye						
	Small (1–2)	21		51.50 (41.16, 61.00)	53.32 (49.33, 61.26)	0.709
	Large (3–4)	64	85	51.50 (37.49, 60.06)	55.28 (44.56, 68.02)	0.454

Footnotes: N = number of participants in each subgroup; n = number of participants with available data for each characteristic. Values are presented as median (IQR). P-values were calculated using the Wilcoxon rank sum test, D = dioptres.

Statistically significant gender differences were observed, with women reporting higher scores on both the Activity Limitation (median: 63.62) and Symptom (median: 64.49) scales compared to men (median: 49.23 and 53.32, respectively; p = 0.003 and p = 0.009). These findings indicate greater perceived impairment and symptom severity among female patients.

In contrast, surgical treatments (keratoplasty, corneal cross-linking) and visual correction methods (glasses, contact lenses, or no correction) did not significantly affect patient-reported quality of life scores. Additionally, no statistically significant correlation was found between keratoconus severity stages (grades I–II vs. III–IV) and subjective quality of life assessments.

Correlations between clinical parameters and KORQ questionnaire outcomes

Table 5 presents biweight midcorrelation coefficients assessing the relationship between clinical parameters and Activity Limitation Scale scores from the Keratoconus Outcomes Research Questionnaire (KORQ), where higher scores indicate greater functional impairment. The analysis revealed statistically significant correlations primarily involving corneal aberrations. Higher-order aberrations (HOA) in both the better-seeing eye (rbicor = 0.23; p = 0.019) and worse-seeing eye (rbicor = 0.26; p = 0.009) were positively correlated with increased activity limitations, suggesting that greater aberrations are associated with worse visual function. Horizontal coma aberration in the better-seeing eye showed the strongest correlation (rbicor = 0.33; p < 0.001), while vertical coma (rbicor = 0.27; p = 0.006) and spherical aberration (rbicor = 0.22; p = 0.031) were significantly associated with worse scores in the worse-seeing eye. Additionally, trefoil aberration at 30° in the better-seeing eye correlated significantly with higher activity limitation scores (rbicor = 0.30; p = 0.002). Interestingly, steeper maximum keratometry (Kmax) values in the worse-seeing eye were associated with higher activity limitation scores (negative correlation, rbicor = -0.21; p = 0.035), indicating that steeper corneas correlate with poorer visual function. In contrast, standard refractive measures, including visual acuity (UVA, BCVA), astigmatism, and corneal thickness, did not show significant correlations with patients' subjective assessments of daily activity limitations.

Table 6 presents biweight midcorrelation coefficients evaluating the relationships between clinical parameters and patient-reported symptoms, as measured by the Keratoconus Outcomes Research Questionnaire (KORQ) Symptom Scale. The analysis reveals significant associations primarily involving corneal aberrations, particularly in the worse-seeing eye. Higher-order aberrations (HOA) in the worse-seeing eye showed the strongest correlation with increased symptom severity (rbicor = 0.44; p < 0.001). Other significant correlations in the worse-seeing eye included vertical coma (rbicor = 0.41; p < 0.001), horizontal coma (rbicor = 0.27; p = 0.006), total RMS error (rbicor = 0.27; p = 0.007), spherical aberration (rbicor = 0.23; p = 0.021), trefoil at 30° (rbicor = 0.22; p = 0.031), and astigmatism aberration at 0° (rbicor = 0.29; p = 0.003). Conversely, standard refractive parameters, including visual acuity (UVA, BCVA), astigmatism values, maximum keratometry (Kmax), and corneal thickness metrics (CCT, MCT), showed no significant correlations with symptom severity. These findings highlight higher-order corneal aberrations—particularly coma and spherical aberrations in the worse-seeing eye—as key predictors of subjective visual symptom burden in keratoconus patients. This suggests that interventions specifically targeting these aberrations may provide meaningful symptomatic relief and improve patient-perceived quality of vision.

Robust linear regression models adjusted for age and gender: associations between clinical parameters and activity limitation & symptom scores

Table 7 presents the results of robust linear regression models adjusted for age and gender, assessing the associations between clinical

Table 5
Biweight midcorrelation between activity limitation scale score and clinical variables in patients with keratoconus (N = 100).

Parameter	*N*	r_{bicor}	*95% CI*	*p-value*
Age [yrs]	100	-0.12	-0.31, 0.08	0.235
Astigmatism better eye [D]	100	-0.05	-0.24, 0.15	0.618
Astigmatism worse eye [D]	100	0.01	-0.18, 0.21	0.885
UVA better eye	100	0.00	-0.19, 0.20	0.980
UVA worse eye	100	0.08	-0.12, 0.27	0.435
BCVA better Eye	100	-0.14	-0.33, 0.05	0.154
BCVA worse Eye	100	-0.03	-0.23, 0.17	0.762
Total UVA (total UVA = UVA better eye + UVA worse eye	100	0.04	-0.16, 0.24	0.686
Total BCVA (total BCVA = BCVA better eye + BCVA worse eye)	100	-0.10	-0.29, 0.10	0.321
BCVA Asymmetry (BCVA Asymmetry= BCVA better eye − BCVA worse eye)	100	-0.15	-0.33, 0.05	0.144
Kmax better eye [D]	100	-0.13	-0.32, 0.07	0.192
Kmax worse eye [D]	100	-0.21	-0.39, -0.01	**0.035**
CCT better eye [μm]	100	0.09	-0.11, 0.28	0.369
CCT worse eye [μm]	100	0.16	-0.04, 0.35	0.113
MCT better eye [μm]	100	0.08	-0.12, 0.27	0.447
MCT worse eye [μm]	100	0.15	-0.05, 0.33	0.150
TG (thickness gradient) = |CCT-MCT| better eye [μm]	100	-0.03	-0.23, 0.17	0.758
TG (thickness gradient) = |CCT-MCT| worse eye [μm]	100	-0.11	-0.30, 0.09	0.288
RMS Error better eye [μm]	41	0.19	0.00, 0.38	0.052
RMS HOA better eye [μm]	41	0.23	0.04, 0.41	**0.019**
Horizontal Coma better eye [μm]	41	0.33	0.15, 0.50	**< 0.001**
Vertical Coma better eye [μm]	41	0.03	-0.17, 0.22	0.799
Spherical Aberration better eye [μm]]	41	0.18	-0.02, 0.36	0.078
Trefoil (180°) better eye [μm]	41	0.16	-0.04, 0.35	0.106
Trefoil (30°) better eye [μm]	41	0.30	0.11, 0.47	**0.002**
Astigmatism (45°) better eye [μm]	41	-0.05	-0.24, 0.15	0.638
Astigmatism (0°) better eye [μm]	41	0.15	-0.05, 0.33	0.145
RMS Error worse eye [μm]	40	0.09	-0.11, 0.87	0.389
RMS HOA worse eye [μm]	40	0.26	0.07, 0.43	**0.009**
Horizontal coma worse eye [μm]	40	0.26	0.07, 0.44	**0.008**
Vertical Coma worse eye [μm]	40	0.27	0.08, 0.44	**0.006**
Spherical Aberration worse eye [μm]	40	0.22	0.02, 0.40	**0.031**
Trefoil (180°) worse eye [μm]	40	-0.08	-0.28, 0.11	0.403
Trefoil (30°) worse eye [μm]	40	0.06	-0.13, 0.26	0.527
Astigmatism (45°) worse eye [μm]	40	0.06	-0.14, 0.25	0.559
Astigmatism (0°) worse eye [μm]	40	-0.09	-0.28, 0.11	0.387

Footnotes: N = total cohort size; n = number of participants with complete data for each variable pair. 95% confidence intervals (CI) were estimated using 1000 bootstrap replicates; D = diopters; μm = micrometers; VIScc = visual acuity composite score; P-values < 0.05 indicate statistical significance.

Table 6
Biweight midcorrelation between symptoms scale score and clinical variables in patients with keratoconus (N = 100).

Parameter	*N*	r_{bicor}	*95% CI*	*p-value*
Age [yrs]	100	-0.12	-0.31, 0.08	0.245
Astigmatism better eye [D]	100	0.07	-0.13, 0.26	0.498
Astigmatism worse eye [D]	100	0.14	-0.06, 0.32	0.175
UVA better eye	100	0.02	-0.18, 0.22	0.838
UVA worse eye	100	0.11	-0.09, 0.30	0.279
BCVA better Eye	100	-0.11	-0.30, 0.09	0.287
BCVA worse Eye	100	-0.05	-0.24, 0.15	0.645
Total UVA (total UVA = UVA better eye + UVA worse eye	100	0.04	-0.16, 0.23	0.727
Total BCVA (total BCVA = BCVA better eye + BCVA worse eye)	100	-0.09	-0.29, 0.10	0.349
BCVA Asymmetry (BCVA Asymmetry= BCVA better eye − BCVA worse eye)	100	-0.08	-0.28, 0.11	0.407
Kmax better eye [D]	100	-0.08	-0.27, 0.12	0.439
Kmax worse eye [D]	100	-0.09	-0.28, 0.11	0.360
CCT better eye [μm]	100	-0.01	-0.20, 0.19	0.956
CCT worse eye [μm]	100	0.05	-0.15, 0.24	0.624
MCT better eye [μm]	100	-0.04	-0.24, 0.16	0.680
MCT worse eye [μm]	100	0.05	-0.15, 0.25	0.614
TG (thickness gradient) = |CCT-MCT| better eye [μm]	100	0.15	-0.05, 0.33	0.142
TG (thickness gradient) = |CCT-MCT| worse eye [μm]	100	0.01	-0.18,0.21	0.904
RMS Error better eye [μm]	41	0.05	-0.15, 0.24	0.655
RMS HOA better eye [μm]	41	0.07	-0.13, 0.26	0.481
Horizontal Coma better eye [μm]	41	0.14	-0.05, 0.33	0.150
Vertical Coma better eye [μm]	41	-0.09	-0.28, 0.11	0.378
Spherical Aberration better eye [μm]	41	0.03	-0.17, 0.22	0.786
Trefoil (180°) better eye [μm]	41	-0.03	-0.23, 0.16	0.747
Trefoil (30°) better eye [μm]	41	0.10	-0.10, 0.29	0.332
Astigmatism (45°) better eye [μm]	41	-0.27	-0.44, -0.08	**0.007**
Astigmatism (0°) better eye [μm]	41	0.19	0.00, 0.37	0.055
RMS Error worse eye [μm]	40	0.27	0.08, 0.44	**0.007**
RMS HOA worse eye [μm]	40	0.44	0.27, 0.59	**< 0.001**
Horizontal Coma worse eye [μm]	40	0.27	0.08, 0.45	**0.006**
Vertical Coma worse eye [μm]	40	0.41	0.23, 0.56	**< 0.001**
Spherical Aberration worse eye [μm]	40	0.23	0.04, 0.41	**0.021**
Trefoil (180°) worse eye [μm]	40	0.17	-0.03, 0.36	0.090
Trefoil (30°) worse eye [μm]	40	0.22	0.02, 0.40	**0.031**
Astigmatism (45°) worse eye [μm]	40	0.12	-0.07, 0.31	0.220
Astigmatism (0°) worse eye [μm]	40	0.29	0.10, 0.46	**0.003**

Footnotes: N = total cohort size; n = number of participants with complete data for each variable pair. 95% confidence intervals (CI) were estimated using 1000 bootstrap replicates; D = dioptres; μm = micrometers; VIScc = visual acuity composite score; P-values < 0.05 indicate statistical significance.

parameters and Activity Limitation Scale scores from the Keratoconus Outcomes Research Questionnaire (KORQ). The analysis identified significant associations, primarily involving visual acuity and corneal aberrations. Notably, better best-corrected visual acuity (BCVA) in the better-seeing eye was significantly associated with lower perceived activity limitations (β = -12.13; p = 0.042). In contrast, higher-order aberrations (HOA) in the worse-seeing eye were positively correlated with increased activity limitation scores (β = 2.75; p = 0.033). Additionally, specific aberrations in the worse-seeing eye, including horizontal coma (β = 6.33; p = 0.003) and vertical coma (β = 8.08; p = 0.015), demonstrated strong associations with greater functional impairment. Trefoil aberration (180°) in the better-seeing eye also showed a significant association (β = 16.45; p = 0.021). Conversely, traditional refractive parameters such as astigmatism, uncorrected visual acuity, corneal thickness, and maximum keratometry values did not exhibit statistically significant associations with activity limitations. These findings underscore the critical role of best-corrected visual acuity in the better-seeing eye and the impact of higher-order corneal aberrations, particularly coma, on subjective activity limitations in keratoconus patients. Thus, clinical management strategies aimed at optimizing visual acuity and minimizing higher-order aberrations may effectively reduce patient-perceived functional impairment.

Table 8 presents the results of robust linear regression models, adjusted for age and gender, examining the associations between clinical parameters and Symptom Scale scores from the Keratoconus Outcomes Research Questionnaire (KORQ). The analysis identified significant associations, particularly involving best-corrected visual acuity (BCVA) and corneal aberrations.

Better BCVA in the better-seeing eye was significantly associated with lower symptom severity (β = -9.83; p = 0.047), indicating that improved visual acuity corresponds to reduced visual discomfort. In contrast, corneal aberrations in the worse-seeing eye were strongly correlated with increased symptom severity, particularly higher-order aberrations (HOA; β = 2.84; p = 0.004), horizontal coma (β = 4.39; p = 0.006), vertical coma (β = 5.83; p = 0.019), trefoil aberration at 180° (β = 5.23; p = 0.020), and total RMS error (β = 0.54; p = 0.042).

Conversely, standard refractive measures, including astigmatism, uncorrected visual acuity, maximum keratometry values, and corneal thickness parameters, did not significantly predict symptom scores.

Table 7
Regression coefficients for individual exposures adjusted for patients' age and gender on the Activity Limitation scale score using a robust linear model.

Exposure	*N*	*β*	*95% CI*	*p-value*
Astigmatism better eye [D]	100	-0.08	-1.52, 1.37	0.917
Astigmatism worse eye [D]	100	-0.11	-1.17, 0.96	0.845
UVA better eye	100	-4.93	-17.04, 7.18	0.421
UVA worse eye	100	12.18	-16.02, 40.38	0.394
BCVA better Eye	100	-12.13	-23.81, -0.46	**0.042**
BCVA worse Eye	100	-5.20	-18.94, 8.54	0.454
Total UVA (total UVA = UVA better eye + UVA worse eye	100	-1.46	-11.49, 8.57	0.773
Total BCVA (total BCVA = BCVA better eye + BCVA worse eye)	100	-6.04	-12.86, 0.79	0.082
BCVA Asymmetry (BCVA Asymmetry = BCVA better eye − BCVA worse eye)	100	-11.61	-23.11, 1.06	0.072
Kmax better eye [D]	100	-0.10	-0.61, 0.41	0.694
Kmax worse eye [D]	100	-0.30	-0.62, 0.03	0.071
CCT better eye [μm]	100	0.01	-0.05, 0.07	0.681
CCT worse eye [μm]	100	0.02	-0.02, 0.07	0.354
MCT better eye [μm]	100	0.01	-0.03, 0.06	0.565
MCT worse eye [μm]	100	0.01	-0.02, 0.05	0.440
TG (thickness gradient) = |CCT-MCT| better eye [μm]	100	-0.02	-0.11, 0.07	0.656
TG (thickness gradient) = |CCT-MCT| worse eye [μm]	100	-0.01	-0.08, 0.06	0.792
RMS Error better eye [μm]	41	0.82	-0.56, 2.21	0.235
RMS HOA better eye [μm]	41	3.90	-0.20, 8.01	0.062
Horizontal Coma better eye [μm]	41	-0.03	-0.10, 0.04	0.470
Vertical Coma better eye [μm]	41	1.67	-2.83, 6.18	0.456
Spherical Aberration better eye [μm]	41	13.46	-2.41, 29.32	0.094
Trefoil Aberration (180°) better eye [μm]	41	16.45	2.65, 30.26	**0.021**
Trefoil (30°) better eye [μm]	41	17.46	-0.52, 35.45	0.057
Astigmatism (45°) better eye [μm]	41	0.06	-7.76, 7.88	0.988
Astigmatism (0°) better eye [μm]	41	2.66	-3.39, 8.71	0.378
RMS Error worse eye [μm]	40	0.46	-0.32, 1.23	0.238
RMS HOA worse eye [μm]	40	2.75	0.24, 5.25	**0.033**
Horizontal Coma worse eye [μm]	40	6.33	2.35, 10.32	**0.003**
Vertical Coma worse eye [μm]	40	8.08	1.70, 14.46	**0.015**
Spherical Aberration worse eye [μm]	40	3.22	-0.67, 7.11	0.102
Trefoil (180°) worse eye [μm]	40	3.86	-2.27, 10.00	0.210
Trefoil (30°) worse eye [μm]	40	-0.04	-0.10, 0.03	0.259
Astigmatism (45°) worse eye [μm]	40	1.55	-1.21, 4.30	0.263
Astigmatism (0°) worse eye [μm]	40	-0.82	-4.44, 2.81	0.650

Footnote: β – regression coefficient; 95% CI – 95% confidence interval.

Table 8
Regression coefficients for individual exposures adjusted for patients' age and gender on the symptoms scale score using a robust linear model.

Exposure	*N*	*β*	*95% CI*	*p-value*
Astigmatism better eye [D]	100	0.77	-0.45, 1.99	0.214
Astigmatism worse eye [D]	100	0.44	-0.50, 1.39	0.355
UVA better eye	100	-3.99	-14.52, 6.54	0.454
UVA worse eye	100	-1.86	-27.22, 23.50	0.855
Best-Corrected Visual Acuity Better Eye	100	-9.83	-19.55, - 0.11	**0.047**
Best-Corrected Visual Acuity, Worse Eye	100	-6.05	-17.65, 5.54	0.303
Total UVA (total UVA = UVA better eye + UVA worse eye	100	-2.75	-11.17, 5.66	0.518
Total BCVA (total BCVA = BCVA better eye + BCVA worse eye)	100	-5.13	-11.06, 0.80	0.089
BCVA Asymmetry (BCVA Asymmetry = BCVA better eye − BCVA worse eye)	100	-7.12	-18.89, 7.14	0.323
Kmax better eye [D]	100	-0.08	-0.53, 0.38	0.738
Kmax worse eye [D]	100	-0.13	-0.42, 0.16	0.373
CCT better eye [μm]	100	0.01	-0.05, 0.06	0.758
CCT worse eye [μm]	100	0.00	-0.04, 0.04	0.962
MCT better eye [μm]	100	0.00	-0.04, 0.04	0.926
MCT worse eye [μm]	100	0.01	-0.03, 0.04	0.723
TG (thickness gradient) = |CCT-MCT| better eye [μm]	100	0.04	-0.04, 0.12	0.323
TG (thickness gradient) = |CCT-MCT| worse eye [μm]	100	-0.02	-0.08, 0.04	0.434
RMS Error better eye [μm]	41	0.16	-0.87, 1.19	0.750
RMS HOA better eye [μm]	41	1.31	-2.01, 4.62	0.429
Horizontal Coma better eye [μm]	41	0.00	-0.06, 0.05	0.927
Vertical Coma better eye [μm]	41	0.44	-2.93, 3.81	0.793
Spherical Aberration better eye [μm]	41	2.81	-9.78, 15.39	0.654
Trefoil Aberration (180°) better eye [μm]	41	5.73	-5.75, 17.20	0.319
Trefoil (30°) better eye [μm]	41	4.61	-10.91, 20.13	0.551
Astigmatism (45°) better eye [μm]	41	-3.81	-9.71, 1.98	0.188
Astigmatism (0°) better eye [μm]	41	2.92	-1.75, 7.59	0.213
RMS Error worse eye [μm]	40	0.54	0.02, 1.06	**0.042**
RMS HOA worse eye [μm]	40	2.84	0.99, 4.70	**0.004**
Horizontal Coma worse eye [μm]	40	4.39	1.33, 7.44	**0.006**
Vertical Coma worse eye [μm]	40	5.83	1.00, 10.66	**0.019**
Spherical Aberration worse eye [μm]	40	2.19	-0.88, 5.26	0.157
Trefoil (180°) worse eye [μm]	40	5.23	0.86, 9.60	**0.020**
Trefoil (30°) worse eye [μm]	40	0.01	-0.04, 0.05	0.802
Astigmatism (45°) worse eye [μm]	40	1.69	-0.23, 3.61	0.082
Astigmatism (0°) worse [μm]	40	2.52	-0.21, 5.25	0.069

Footnote: β – regression coefficient; 95% CI – 95% confidence interval

These findings emphasize that optimizing best-corrected visual acuity and minimizing higher-order corneal aberrations—particularly coma and trefoil—in the worse-seeing eye are essential for reducing subjective symptom burden and improving perceived visual quality in patients with keratoconus.

Discussion

The study investigated the impact of keratoconus on patients' quality of life by combining objective clinical data with subjective self-assessment using the Polish version of the Keratoconus Outcomes Research Questionnaire (KORQ).

Regarding gender distribution, males represented approximately 80% of participants in our sample. Although keratoconus is generally considered to affect both sexes with similar frequency, some epidemiological studies have reported a modest male predominance, possibly related to environmental or behavioral factors.[33–34] In our cohort, the male predominance was likely incidental and may reflect local referral patterns or lower participation rates among women in examinations requiring full aberrometric assessment and completion of questionnaires. Nevertheless, this imbalance should be considered when interpreting and generalizing the results to the broader keratoconus population.

No significant differences in KORQ scores were observed between patients who had undergone surgical interventions (corneal cross-linking or keratoplasty) and those who had not. This finding is consistent with Pomberger et al[5], who reported similar outcomes in a German cohort, where surgical procedures did not significantly alter subjective visual function. However, Pinto et al.[13] found that patients who had undergone cross-linking reported worse functional scores, possibly due to post-procedural discomfort or incomplete visual recovery.

Patients reported the greatest difficulties in daily functioning during tasks requiring distance vision, in low-light conditions, and while driving at night. Visual symptoms such as distorted vision, dry eyes, fatigue, and discomfort in dusty or smoky environments significantly affected their quality of life. These results are consistent with previously published papers. The average score for the Activity Limitation subscale was 51.53 (SD = 17.19) and for the Symptom subscale 55.60 (SD = 16.14), indicating a moderate but meaningful impact of keratoconus on everyday functioning. Results were closely aligned with those found in studies by Alatawi[36] in Saudi Arabia and Kandel et al. in Australia.[37] Slightly higher scores, particularly in the Activity Limitation (AL) subscale, were reported by Pinto et al.[7] in Portugal. These results suggest a consistent pattern of patient-reported outcomes across diverse populations.

The study demonstrated a clear and statistically significant difference in Activity Limitation and symptoms between male and female patients, suggesting a potential influence of sex-related factors on the perceived impact of keratoconus. Women reported greater functional impairments and more severe visual symptoms than men. These findings are consistent with those of Al Bdour et al.[38] and Gothwal et al.[12] also identified gender-based disparities in keratoconus-related quality of life. Potential explanations for this difference may include differences in the perception of discomfort, as women may be more sensitive to irritation, dryness, or photophobia, a greater tendency to report symptoms, and possible hormonal differences affecting the tear film and ocular surface stability. However, the influence of gender on vision-related quality of life in patients with keratoconus remains inconclusive, as previous studies have reported conflicting results. Notably, in the univariate analysis conducted by Pinto et al[13], male patients exhibited worse KORQ scores in the functional domain. In the study by Danish researchers Bak-Nielsen et al[6], no significant differences were found between women and men. This may be related to a different clinical profile, a limited number of female participants in other cohorts, or cultural factors influencing symptom reporting. Such exceptions should be considered when interpreting and generalizing the results.

Robust linear regression models, adjusted for age and gender and biweight correlation analyses identified several variables that were significantly associated with scores on both the Activity Limitation and Symptoms subscales of KORQ Questionnaie. These variables are discussed in detail below.

Best-corrected visual acuity (BCVA) in the better-seeing eye emerged as one of the strongest and most consistent predictors of both activity limitation and symptom severity Regression analysis show strong and statistically significant associations between best-corrected visual acuity (BCVA) and both the Activity Limitation and Symptoms subscale scores of the KORQ.

Previous studies have consistently demonstrated that BCVA, particularly in the better-seeing eye, is more strongly associated with patient-reported KORQ scores. For instance, Gothwal et al[12], Kandel et al.[37] and Tan et al.[11] identified BCVA as a key predictor of reduced visual functioning scores across diverse international cohorts. These findings are further supported by Pinto et al.[13] who reported moderate to strong correlations between BCVA and both KORQ subscale scores. Similarly, Ferrini et al.[4] observed a statistically significant relationship between BCVA in the better-seeing eye and both KORQ subscale scores in an Italian population.

Although BCVA did not show statistically significant associations in biweight correlation analyses, it emerged as an independent predictor in multivariate regression models. The lack of statistically significant associations between BCVA and KORQ scores in correlation analyses suggests that the relationship between visual acuity and patient-reported outcomes is not purely linear and may be influenced by other coexisting clinical factors. In particular, the effect of BCVA appears to be modulated by variables such as higher-order aberrations, which may obscure its contribution in univariate correlation analyses. When these factors are accounted for in multivariate regression models, the independent role of BCVA—especially in the better-seeing eye—becomes evident. This finding highlights the importance of multivariable analytical approaches when assessing determinants of vision-related quality of life in keratoconus.

It was demonstrated that there were no statistically significant correlations between KORQ scores and classic tomographic parameters, corneal thickness (CCT/MCT), astigmatism, or thickness gradient. Studies by Al Bdour et al[38], Pomberger et al[5], and Bak-Nielsen et al.[6] similarly reported weak or non-significant associations between topographic measures and QoL outcomes, questioning the clinical relevance of these parameters in isolation. However, a weak but statistically significant correlation was observed for Kmax in the worse-seeing eye in Activity Limitation Scale, although this relationship lost significance in the regression model. Despite the fact, Kmax in the worst-seeing (Activity Limitation subscale) showed a weak but statistically significant correlation (rbicor = 0.21; p = 0.035), which might suggest that greater corneal protrusion is associated with increased functional limitations. However, in regression models that included BCVA and HOA, Kmax lost its significance, confirming that its importance is secondary to more direct factors such as visual acuity and aberrations. A similar pattern was observed in the validation study of the German version of the KORQ questionnaire[5], where, although significant correlations between Kmax and K2 with KORQ scores were found, BCVA emerged as a stronger and more independent predictor of quality of life. These findings reinforce the conclusion that while Kmax may appear important in univariate analyses, in multivariate models it is outweighed by more influential factors.Importantly, several higher-order aberration (HOA) parameters were also identified as significant contributors to reduced quality of life in patients with keratoconus. Our results confirm and reinforce existing evidence that optical and functional parameters (HOAs and BCVA) better predict subjective visual outcomes than corneal curvature metrics alone

Specifically, RMS HOA in the worse-seeing eye was significantly associated with higher KORQ scores in both the Activity Limitation and Symptoms subscales . Moreover, horizontal coma, vertical coma for Activity Limitation and Symptoms subscales, and trefoil aberration at 180° for the Symptoms subscale were all statistically significant predictors.

The results obtained in the Activity Limitations subscale indicate that certain higher-order aberrations have a significant impact on the subjectively perceived functional difficulties in patients with keratoconus.

Both the biweight correlation analysis and regression models consistently demonstrated significant associations for aberrations located in the worse-seeing eye, such as: RMS HOA, horizontal coma, vertical coma., RMS HOA, horizontal coma, vertical coma. Additionally, trefoil aberration at 180° in the better-seeing eye was significant in both the correlation and the regression analyses, (making it one of the few functionally relevant predictors derived from the better eye.

It is worth noting that other aberrations, such as trefoil (30°) or horizontal coma in the better-seeing eye, reached significance only in the correlation analyses but were not significant in regression (although sometimes close to the significance threshold). The reverse situation, significance in regression without a significant correlation, was not observed.

This partial concordance between correlation and regression models suggests that while the impact of HOA on daily functioning is evident, it may be modulated by other clinical factors, such as visual acuity.

In the Visual Symptoms subscale, correlation analyses and regression models showed consistent results, indicating clear and reproducible relationships. Particularly evident was the impact of aberrations originating from the worse-seeing eye, confirming their dominant role in subjective visual discomfort. The following variables were statistically significant in both biweight correlations and regression RMS HOA, vertical coma, horizontal coma, trefoil (180°), RMS Error.Other variables that were significant in correlation but not in regression included: astigmatism (0°), which did not reach significance in the regression model and spherical aberration, which also lost significance when other variables were accounted for.

Aberrations from the better-seeing eye, in turn, did not show significant associations in any of the analyses, further supporting the notion that the image quality in the worse (possibly more distorted) eye dominates the subjective perception of visual symptoms such as halos, blurring, or shape distortions.

The overall agreement between correlation and regression results in this subscale enhances the reliability of the observed associations and emphasizes the importance of selected aberrations. The consistency of findings across analytical approaches underscores the particular relevance of aberrations in the worse-seeing eye, especially coma (horizontal and vertical) and trefoil 180°.

In summary, higher-order aberrations (HOA), particularly those present in the worse-seeing eye, significantly affect the subjectively perceived quality of vision. In the Activity Limitations subscale, their impact was noticeable, though partially modulated by other factors such as BCVA. In the Visual Symptoms subscale, the relationship between HOA and symptom severity was strong and unequivocal, with high consistency between correlation and regression results. The most significant contributors were the coma components, trefoil, and total RMS HOA. These findings suggest that the assessment of visual quality in keratoconus patients should consider not only visual acuity but also the optical image quality, especially in the worse-seeing eye.

Similar relationships were described in the study by Gothwal et al[12], in which total HOA RMS in the worse eye showed a significant association with KORQ outcomes. Unlike Gothwal's study, the present research conducted a detailed analysis of individual aberration components, demonstrating a significant impact of horizontal and vertical coma as well as trefoil aberrations. Importantly, their influence on visual quality remained statistically significant in regression models even after accounting for BCVA, indicating a partially independent effect of HOA.

Previous studies have explored the relationship between visual function and patient-reported outcomes in keratoconus, either through disease-specific tools such as the KORQ, Tan et al.[11] Gothwal et al[12], Pinto et al.[13] or through general visual function questionnaires such as the VFQ Schümmer et al.[14] However, no published KORQ-based study has incorporated detailed aberrometric analysis, and no HOA-based study has assessed quality of life using the KORQ. The present work is, to our knowledge, the first to integrate both approaches by combining a culturally KORQ with component-level HOA data.

Moreover, unlike previous studies that used only total HOA RMS, we analyzed individual aberration components (coma, trefoil, spherical aberration) and their independent and non-linear relationships with KORQ outcomes, separately for the better and worse eye. This multidimensional approach provides a more complete understanding of how optical distortions affect vision-related quality of life and represents the first such analysis in a Central European population.

We would like to discuss several limitations of the present study. One limitation is the relatively small subset of participants (approximately 40 eyes) with complete higher-order aberration data. This limited sample size may have reduced the statistical power to detect weaker associations, particularly in multivariate models including several covariates. Although key relationships between specific aberration components and KORQ outcomes reached statistical significance and were consistent across both subscales, these results should be interpreted with caution. At the same time, the replication of similar effect patterns in both eyes and in sensitivity analyses supports the robustness of the main findings.

Another limitation of this study is that the study population was recruited from a university-affiliated ophthalmology center providing specialized care, which may be associated with a higher proportion of patients with more advanced keratoconus. Although the cohort covered the full spectrum of disease severity, the findings may therefore not be fully representative of keratoconus patients managed exclusively in non-referral or community-based clinical settings. In addition, the limited availability of publicly funded interventions aimed at slowing keratoconus progression prior to 2023 in Poland may have contributed to later referral and more advanced disease at presentation.

Additional limitations related to measurements and methodology should also be considered. Some participants reported alternating between spectacles and contact lenses and were asked to respond based on their most frequently used form of correction. Although this approach was intended to standardize responses, it may have introduced recall bias and recall-related variability in questionnaire responses.

Aberrometry was performed using the Pentacam HR (Oculus), and all HOA values were analyzed for a standardized 6.0-mm pupil, following the device's default settings. Therefore, the observed associations between HOA and KORQ outcomes should be interpreted with caution and verified in larger samples.

Another potential limitation of the study is that visual assessment was primarily based on monocular measurements, whereas visual quality under everyday conditions is inherently binocular. Attempting to relate parameters obtained monocularly to those that may better represent binocular vision is a challenging task and could, to some extent, limit the interpretation of the results. Future research could consider further exploration of binocular vision and the potentially insufficient suppression mechanisms in the more affected eye, which may contribute to discrepancies between optical image quality and subjectively perceived visual performance. Including binocular measurements in future analyses may provide additional insights into the perceptual mechanisms underlying vision in keratoconus.

No statistically significant differences in KORQ scores were observed concerning the stage of disease severity. This result is not surprising, considering that none of the corneal parameters proved to be significant predictors of questionnaire outcomes. Perhaps the use of a classification system that incorporates visual acuity, such as the ABCD grading system[39], would have been a better choice, which represents a potential limitation of our study.

Overall, this study demonstrates that vision-related quality of life in patients with keratoconus is influenced by multiple interacting factors, with optical quality and visual acuity playing a more significant role than corneal structural parameters alone. Both correlation and regression analyses revealed that higher-order aberrations (HOA), particularly in the worse-seeing eye, are strongly associated with the severity of subjective visual symptoms. Moreover, best-corrected visual acuity (BCVA) in the better-seeing eye emerged as an independent and consistent predictor of both functional limitations and symptom burden, as measured by the KORQ questionnaire.

These findings carry important clinical implications. They challenge the conventional structure-based model of assessment and highlight the need for a more comprehensive understanding of visual function. Recognizing the role of the worse-seeing eye, often overlooked in routine evaluation, may be crucial for accurately assessing a patient's difficulties. Moreover, the results support the integration of subjective assessment tools, such as patient-reported outcome measures like the KORQ, into routine clinical care to better capture the real-world impact of the disease.

Ultimately, the goal of keratoconus management should not be limited to improving clinical metrics alone. A more holistic and individualized approach, incorporating both objective data and the patient's perspective, may lead to more effective and meaningful therapeutic decisions.

Conclusion

Best-corrected visual acuity (BCVA) is a key determinant of vision-related quality of life in patients with keratoconus, playing a more important role than corneal structural parameters. Higher-order aberrations (HOAs), particularly in the worse-seeing eye, are significantly associated with greater symptom severity and functional limitations. The results show that improving best-corrected visual acuity (BCVA) and reducing higher-order aberrations should be the main goals of treatment to enhance patients' vision and everyday functioning.

Ethical approval

The study was approved by the Bioethics Committee of the Medical University of Silesia, Katowice, Poland (protocol code: BNW/NWN/0052/KBI/70/23, date of approval: 11 July 2023).

Informed consent

Informed consent was obtained from all individual participants included in the study. The privacy rights of patients were always observed.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the author(s) used ChatGPT (OpenAI) in order to improve language and grammar. After using this tool, the author(s) reviewed and edited the content as needed and take (s) full responsibility for the content of the publication.

Author contributions

Conceptualization, M.N. and E.W.; methodology, M.N. and A.W.; formal analysis, E.W., A.W. and M.N.; investigation, D.S., M.K., M.N. and B. M.; data curation A.W. and M.N.; writing—original draft preparation, M.N., J.P; writing—review and editing, E.W., A.W., M.K., D.S. and B.M.; supervision, E.W. and A.W.; project administration, E.W. All authors have read and agreed to the published version of the manuscript.

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Declaration of interests

The authors declare no conflict of interest.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.optom.2025.100604.

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