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Correlation of Corneal Topography with Clinical Findings in Keratoconus

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Abstract

Background: Keratoconus is a progressive, non-inflammatory corneal ectatic disorder characterized by corneal thinning, steepening, irregular astigmatism and progressive visual impairment. Clinical examination remains important for diagnosis; however, corneal topography provides objective quantitative information regarding corneal curvature, elevation and thickness. Correlating topographic parameters with clinical findings may improve assessment of disease severity and facilitate early detection.

Objective: To study the correlation between corneal topographic parameters and clinical findings in patients with keratoconus.

Methods: A hospital-based observational study was conducted at Vasan Eye Care, Shivamogga over a period of 18 months. The study included 168 patients with keratoconus, involving a total of 200 eyes. All participants underwent detailed ophthalmological evaluation, including assessment of visual acuity, refraction, retinoscopy and slit-lamp examination. Clinical signs including scissoring reflex, corneal thinning, Fleischer ring, Vogt striae, Rizzuti sign, Munson sign, corneal protrusion, stromal scarring and acute hydrops were documented. Corneal topography/ tomography was performed to assess keratometric parameters, including K1, K2 and Kmax, corneal astigmatism, central and thinnest corneal thickness, and anterior and posterior corneal elevation. The relationship between clinical findings, disease severity, visual acuity and topographic parameters was evaluated using appropriate statistical methods.

Results: The mean age of the study population was 22.8 ± 6.4 years, with a male predominance (61.3%). Scissoring reflex was the most frequent clinical finding (87.0%), followed by corneal thinning (76.0%) and Fleischer ring (64.0%). The mean Kmax was 55.18 ± 6.42 D, while mean central and thinnest corneal thicknesses were 472.6 ± 39.8 µm and 454.8 ± 41.6 µm, respectively. Kmax showed significant positive correlations with corneal thinning (r=0.46), Fleischer ring (r=0.38), Vogt striae (r=0.49), Rizzuti sign (r=0.51) and Munson sign (r=0.57) (p<0.001 for all).

Kmax increased progressively from mild to advanced/severe disease, whereas corneal thickness decreased significantly (p<0.001). BCVA demonstrated significant correlations with Kmax, K2, corneal astigmatism and corneal elevation, while showing an inverse correlation with thinnest corneal thickness (p<0.001).

Conclusion: Corneal topographic parameters, particularly K max, corneal thickness and elevation indices, demonstrate significant associations with clinical manifestations and severity of keratoconus. Combining detailed clinical examination with corneal topography may facilitate early detection, objective severity assessment and appropriate monitoring of patients with keratoconus.

Keywords: Keratoconus, Corneal Topography, Kmax, Pachymetry, Corneal Elevation, Keratometry, Visual Acuity.

Introduction

Keratoconus is a progressive, non-inflammatory cornealectatic disorder characterized by localized corneal thinning and progressive protrusion of the cornea, resulting in irregular astigmatism and deterioration of visual quality.

The disease commonly presents during adolescence or early adulthood and may progress at variable rates. Clinical manifestations range from minimal refractive abnormalities in early disease to marked corneal distortion, stromal scarring and, occasionally, acute corneal hydrops in advanced disease.[1]

The diagnosis of keratoconusis based on a combination of clinical examination, refraction, retinoscopy, slit-lamp biomicroscopy and corneal imaging. Typical clinical findings include an irregular or scissoring retinoscopic reflex, high or progressive astigmatism, Fleischer ring, Vogt striae, corneal thinning, Rizzuti sign and Munson sign. In advanced disease, stromal scarring and acute hydrops may occur.[2]

Corneal topography has substantially improved the ability to identify abnormalities in corneal shape. Conventional corneal topography evaluates the anterior corneal curvature and provides information regarding asymmetric and inferior corneal steepening. Corneal tomography additionally evaluates anterior and posterior corneal surfaces and corneal thickness distribution. These techniques are particularly valuable in detecting early keratoconus, where slit-lamp examination and conventional keratometry may be inconclusive.[3]

The severity of keratoconusis reflected by several topographic parameters. Maximum keratometry (Kmax), mean keratometry, inferior-superior asymmetry, corneal elevation and minimum or thinnest corneal thickness have been shown to vary with disease severity.

Studies have demonstrated significant correlations between corneal elevation parameters, keratometric measurements and keratoconus severity.[4]

Previous studies have also demonstrated a relationship between clinical manifestations and quantitative topographic abnormalities. In an analysis of keratoconic eyes using Orbscan, maximum keratometry showed one of the strongest associations with clinical manifestations, while minimum pachymetry and corneal elevation were related to visual acuity.[5] Similarly, studies in Indian populations have demonstrated that clinical signs such as scissoring retinoscopy, Munson sign, Vogt striae and corneal scarring tend to be more prominent in eyes with greater topographic abnormalities. [6]

Keratoconus is characteristically bilateral but frequently asymmetric. An apparently clinically normal fellow eye may demonstrate subtle topographic abnormalities, emphasizing the importance of objective corneal imaging in the evaluation of patients with suspected disease.[6] Corneal topography has therefore become an important component of the diagnostic assessment and follow-up of keratoconus. [3]

Despite the availability of sophisticated corneal imaging systems, clinical examination remains essential for diagnosis and assessment of the functional significance of the disease. Establishing the relationship between readily identifiable clinical signs and quantitative topographic parameters may help ophthalmologists recognize disease severity and identify patients requiring closer follow-up or intervention.

The present study was therefore undertaken to evaluate the correlation between corneal topographic parameters and clinical findings among patients with keratoconus presenting to a tertiary ophthalmic centre.

Objectives

Primary objective

To determine the correlation between corneal topographic parameters and clinical findings in patients with keratoconus.

Secondary objectives

1. To describe the demographic and clinical profile of patients with keratoconus.
2. To document the frequency of various clinical signs of keratoconus.
3. To assess the relationship between visual acuity, refractive error and corneal topographic parameters.
4. To assess the association between clinical severity of keratoconus and topographic parameters.
5. To evaluate the relationship between corneal thinning and keratometric/topographic abnormalities.
6. To assess the usefulness of corneal topography in identifying eyes with clinically subtle keratoconus.

Materials and Methods

Study design: A hospital-based observational study was conducted among patients diagnosed with keratoconus.

Study setting: The study was conducted in the Department of Ophthalmology, Vasan Eye Care, Shivamogga.

Study duration: The study was conducted over a period of 18 months.

Study population: Patients diagnosed with keratoconus attending the ophthalmology outpatient department and corneal services during the study period were considered for inclusion.

Sample size: A total of 200 eyes of 168 patients diagnosed with keratoconus were included in the study.

The unit of analysis for ocular parameters was the individual eye.

Inclusion criteria

- Patients fulfilling the clinical and/or topographic criteria for keratoconus were included.
- Patients of either sex were eligible for inclusion.
- Patients who were able to undergo a reliable ophthalmological examination and corneal topography were included.

Exclusion criteria

- Patients with a history of previous corneal surgery or corneal transplantation were excluded.
- Patients with corneal pathology other than keratoconus that could significantly alter corneal topography were excluded.

- Patients with inadequate or unreliable topographic scans were excluded.
- Eyes with significant ocular trauma or other conditions affecting corneal morphology were excluded.

Methods of data collection

Clinical Evaluation

All patients underwent a comprehensive ophthalmological evaluation. A detailed history was obtained regarding presenting symptoms, duration of visual complaints, progression of visual deterioration, photophobia, eye rubbing and previous ocular treatment. Demographic details including age and sex were recorded. Visual acuity was assessed for each eye separately using standard visual acuity charts and was documented as unaided and best-corrected visual acuity. Objective and subjective refraction were performed, and the spherical equivalent and cylindrical refractive error with axis were recorded. Retinoscopywas performed to identify characteristic findings such as a scissoring reflex. Detailed slit-lamp biomicroscopic examination was subsequently carried out to assess the cornea for characteristic clinical features of keratoconus, including localized corneal thinning, conical protrusion, Fleischer ring, Vogt striae, Rizzuti sign, Munson sign, corneal hydrops and stromal corneal scarring. The presence or absence of each clinical sign was documented for individual eyes. The clinical findings were subsequently correlated with the corresponding corneal topographic parameters.

Corneal Topography

Corneal topography was performed in both eyes using the corneal topography/tomography system available at Minto Ophthalmic Hospital, Bengaluru. Patients were appropriately positioned and instructed to fixate on the target during image acquisition. Multiple scans were obtained wherever required, and the best-quality scan satisfying the instrument's quality criteria was selected for analysis. The topographic examination provided quantitative information regarding corneal curvature, astigmatism, corneal steepening, elevation and pachymetric distribution. The recorded parameters included flat keratometry (K1), steep keratometry (K2), mean keratometry, maximum keratometry (Kmax), corneal astigmatism, anterior and posterior corneal elevation, central corneal thickness and thinnest corneal thickness. Relevant keratoconus-specific indices generated by the imaging system were also recorded where available. The topographic findings were assessed for characteristic patterns of keratoconus, including inferior or inferotemporal steepening, asymmetric corneal curvature and localized thinning. These parameters were subsequently compared with the clinical findings and visual and refractive characteristics of the corresponding eyes.

Assessment of Keratoconus Severity

The severity of keratoconus was assessed by integrating the clinical examination findings with the corneal topographic and pachymetric parameters. Each eye was evaluated individually because keratoconus may demonstrate considerable asymmetry between fellow eyes. Disease severity was categorized according to the classification system applicable to the corneal imaging modality used in the study. Where the Amsler-Krumeich classification was applicable, severity was determined on the basis of keratometric readings, refractive error, corneal thickness and clinical findings. Increasing K max, greater corneal steepening and increasing irregular astigmatism were considered indicators of more advanced ectatic changes, while decreasing thinnest corneal thickness and increasing corneal elevation were considered markers of progressive structural alteration. The relationship between severity grade and individual clinical signs such as corneal thinning, Fleischer ring, Vogt striae, Munson sign, Rizzuti sign and corneal scarring was evaluated. The correlation between clinical severity and quantitative topographic parameters was subsequently analysed statistically to determine the strength and significance of these associations.

Assessment of Keratoconus Severity

Keratoconus severity was assessed using the classification system applicable to the corneal imaging system used at the study centre. Where Amsler-Krumeich classification was available, severity was categorized according to keratometric, refractive, corneal thickness and slit-lamp parameters.

The relationship between severity grade and quantitative topographic parameters was evaluated.

Statistical Analysis

Data were entered into a structured database and analysed using appropriate statistical software.

Continuous variables were expressed as mean ± standard deviation or median with interquartile range depending on the distribution of data. Categorical variables were expressed as frequencies and percentages. The association between categorical clinical findings and keratoconus severity was assessed using the Chi-square test or Fisher's exact test, as appropriate. For comparison of continuous topographic parameters between groups, the independent-samples t-test or Mann–Whitney U test was used depending on data distribution. For comparison between more than two groups, one-way ANOVA or Kruskal–Wallis test was applied as appropriate. Correlation between clinical/visual parameters and continuous topographic parameters was assessed using Pearson's or Spearman's correlation coefficient.

A p-value <0.05 was considered statistically significant.

Results

Table 1: Demographic characteristics of the study participants (n=168)

Variable	Number (%) / Mean ± SD
Age (years), mean ± SD	22.8 ± 6.4
Age range (years)	12–42
Age group	
≤15 years	18 (10.7)
16–20 years	52 (31.0)
21–30 years	76 (45.2)
>30 years	22 (13.1)
Sex	
Male	103 (61.3)
Female	65 (38.7)
Male: Female ratio	1.58:1
Laterality	
Bilateral involvement	32 (19.0)
Unilateral involvement	136 (81.0)

Table 1 shows the demographic characteristics of the 168 patients included in the study. The mean age of the study participants was 22.8 ± 6.4 years, with an age range of 12–42 years. The majority of patients belonged to the 21–30-year age group (45.2%), followed by those aged 16–20 years (31.0%). There was a male predominance, with 103 (61.3%) males and 65 (38.7%) females, giving a male-to-female ratio of 1.58:1. Bilateral keratoconuswas observed in 32 patients (19.0%), while 136 patients (81.0%) had unilateral involvement according to the study's eye-level classification.

Table 2: Clinical findings among the 200 eyes with keratoconus

Clinical finding	Number of eyes	Percentage
Scissoring reflex on retinoscopy	174	87
Corneal thinning	152	76
Fleischer ring	128	64
Vogt striae	72	36
Rizzuti sign	58	29
Munson sign	36	18
Corneal protrusion	91	45.5
Corneal stromal scarring	24	12
Acute corneal hydrops	4	2

Table 2 presents the distribution of clinical findings among the 200 eyes with keratoconus. A scissoring reflex on retinoscopy was the most frequent finding, observed in 174 eyes (87.0%), followed by corneal thinning in 152 eyes (76.0%) and Fleischer ring in 128 eyes (64.0%). Vogt striae were present in 72 eyes (36.0%), while Rizzuti sign and Munson sign were observed in 58 (29.0%) and 36 (18.0%) eyes, respectively. Corneal protrusion was noted in 91 eyes (45.5%). Corneal stromal scarring was present in 24 eyes (12.0%), whereas acute corneal hydrops was uncommon and was observed in only 4 eyes (2.0%).

Table 3: Visual and refractive characteristics of the study eyes (n=200)

Parameter	Mean ± SD	Range
Unaided visual acuity (log MAR)	0.48 ± 0.31	0.00–1.30
Best-corrected visual acuity (log MAR)	0.18 ± 0.20	0.00–1.00
Spherical error (D)	−2.16 ± 2.34	−12.00 to +3.00
Cylindrical error (D)	−3.18 ± 1.72	−8.50 to −0.50
Spherical equivalent (D)	−3.75 ± 2.48	−13.00 to +1.50
Keratometric astigmatism (D)	4.12 ± 2.11	0.80–11.20

Table 3 describes the visual and refractive characteristics of the 200 study eyes. The mean unaided visual acuity was 0.48 ± 0.31 logMAR, which improved to 0.18 ± 0.20 logMAR with best correction. The mean spherical refractive error was −2.16 ± 2.34 D, while the mean cylindrical error was −3.18 ± 1.72 D. The mean spherical equivalent was −3.75 ± 2.48 D. Mean keratometric astigmatism was 4.12 ± 2.11 D, indicating a substantial astigmatic component among the study eyes.

Table 4: Corneal topographic and pachymetric parameters among study eyes (n=200)

Topographic parameter	Mean ± SD	Range
K1 (D)	46.12 ± 3.42	40.20–57.80
K2 (D)	50.26 ± 4.18	42.10–64.20
Mean keratometry (D)	48.19 ± 3.62	41.30–60.80
Kmax (D)	55.18 ± 6.42	45.10–72.40
Corneal astigmatism (D)	4.14 ± 2.08	0.80–11.30
Central corneal thickness (µm)	472.6 ± 39.8	382–558
Thinnest corneal thickness (µm)	454.8 ± 41.6	361–541
Anterior elevation (µm)	24.8 ± 13.2	2–68
Posterior elevation (µm)	31.6 ± 15.4	4–79

Table 4 presents the corneal topographic and pachymetric parameters of the study eyes. The mean K1 and K2 values were 46.12 ± 3.42 D and 50.26 ± 4.18 D, respectively, with a mean keratometry of 48.19 ± 3.62 D. The mean Kmax was 55.18 ± 6.42 D. Mean corneal astigmatism was 4.14 ± 2.08 D. The mean central corneal thickness was 472.6 ± 39.8 µm, while the mean thinnest corneal thickness was 454.8 ± 41.6 µm. The mean anterior and posterior elevation values were 24.8 ± 13.2 µm and 31.6 ± 15.4 µm, respectively. These findings demonstrate the characteristic corneal steepening, astigmatism and thinning associated with keratoconus.

Table 5: Distribution of keratoconus according to severity

Severity grade	Number of eyes	Percentage
Grade I – Mild	62	31
Grade II – Moderate	78	39
Grade III – Advanced	44	22
Grade IV – Severe	16	8
Total	200	100

Table 5 demonstrates the distribution of study eyes according to the severity of keratoconus. Mild keratoconuswas observed in 62 eyes (31.0%), while moderate disease was the most common category, affecting 78 eyes (39.0%). Advanced keratoconus was present in 44 eyes (22.0%), and severe disease was observed in 16 eyes (8.0%). Thus, the majority of eyes belonged to the mild-to-moderate severity categories, while approximately one-third demonstrated advanced or severe disease.

Table 6: Correlation of clinical findings with maximum keratometry (Kmax)

Clinical finding	Kmax Mean ± SD (D)	Correlation coefficient (r)	p-value
Corneal thinning present	58.24 ± 6.21	0.46	<0.001

Corneal thinning absent	51.32 ± 4.12		
Fleischer ring present	57.46 ± 6.08	0.38	<0.001
Fleischer ring absent	51.12 ± 4.56		
Vogt striae present	61.18 ± 5.72	0.49	<0.001
Vogt striae absent	52.82 ± 5.02		
Rizzuti sign present	62.14 ± 5.34	0.51	<0.001
Rizzuti sign absent	52.34 ± 5.18		
Munson sign present	66.28 ± 4.86	0.57	<0.001
Munson sign absent	52.76 ± 5.24		
Corneal scarring present	67.12 ± 4.72	0.42	<0.001
Corneal scarring absent	53.54 ± 5.64		

Table 6 shows the relationship between clinical findings and maximum keratometry (Kmax). Eyes demonstrating clinical features suggestive of more advanced keratoconus had significantly higher mean Kmax values. The mean Kmax was higher among eyes with corneal thinning, Fleischer ring, Vogt striae, Rizzuti sign, Munson sign and corneal scarring compared with eyes without these respective findings. Significant positive correlations were observed between Kmax and the major clinical findings. The strongest correlation was observed with Munson sign (r=0.57, p<0.001), followed by Rizzuti sign (r=0.51, p<0.001) and Vogt striae (r=0.49, p<0.001). These findings indicate that increasing corneal steepening on topography is associated with more prominent clinical manifestations of keratoconus.

Table 7: Correlation between keratoconus severity and topographic parameters

Parameter	Mild (n=62) Mean ± SD	Moderate (n=78) Mean ± SD	Advanced/Severe (n=60) Mean ± SD	p-value
K1 (D)	43.82 ± 1.84	46.28 ± 2.36	49.14 ± 3.62	<0.001
K2 (D)	46.18 ± 2.24	49.72 ± 2.86	55.16 ± 4.18	<0.001
Kmax (D)	48.82 ± 2.34	54.26 ± 3.48	63.42 ± 5.18	<0.001
Corneal astigmatism (D)	2.36 ± 0.82	3.84 ± 1.24	6.42 ± 2.16	<0.001
Central corneal thickness (µm)	498.2 ± 26.4	468.6 ± 29.8	446.8 ± 36.2	<0.001
Thinnest corneal thickness (µm)	484.6 ± 27.8	452.4 ± 31.6	425.8 ± 37.4	<0.001
Anterior elevation (µm)	14.2 ± 5.8	24.6 ± 8.4	36.8 ± 12.6	<0.001
Posterior elevation (µm)	20.8 ± 7.2	31.4 ± 10.2	44.6 ± 13.8	<0.001

Table 7 compares corneal topographic parameters across different severity grades of keratoconus. There was a progressive increase in K1, K2 and Kmax with increasing disease severity. Mean Kmax increased from 48.82 ± 2.34 D in mild disease to 54.26 ± 3.48 D in moderate disease and 63.42 ± 5.18 D in advanced/severe disease. Similarly, corneal astigmatism and anterior and posterior elevation increased significantly with increasing severity. In contrast, central corneal thickness and thinnest corneal thickness progressively decreased across severity categories. All differences were statistically significant ($p<0.001$), demonstrating a strong relationship between topographic abnormalities and clinical severity.

Table 8: Correlation of visual acuity with selected corneal topographic parameters

Parameter	Correlation with BCVA (log MAR), r	p-value
Kmax	0.48	<0.001
K2	0.41	<0.001
Corneal astigmatism	0.44	<0.001
Thinnest corneal thickness	−0.36	<0.001
Anterior elevation	0.32	<0.001
Posterior elevation	0.35	<0.001

Table 8 demonstrates the correlation between best-corrected visual acuity and selected corneal topographic parameters. BCVA showed a significant positive correlation with Kmax ($r=0.48$, $p<0.001$), K2 ($r=0.41$, $p<0.001$), corneal astigmatism ($r=0.44$, $p<0.001$), anterior elevation ($r=0.32$, $p<0.001$) and posterior elevation ($r=0.35$, $p<0.001$). An inverse correlation was observed between BCVA and thinnest corneal thickness ($r=-0.36$, $p<0.001$). Thus, greater corneal steepening, astigmatism and elevation were associated with poorer visual acuity, whereas greater residual corneal thickness was associated with better visual function.

Discussion

Keratoconus is a progressive corneal ectatic disorder characterized by progressive corneal thinning, steepening, irregular astigmatism and deterioration of visual function. The present study evaluated the correlation between clinical findings and corneal topographic parameters among 200 eyes of 168 patients with keratoconus attending Minto Ophthalmic Hospital, Bengaluru, over a period of 1.5 years. The study demonstrated a significant association between clinical manifestations of keratoconus and objective topographic parameters, particularly maximum keratometry (Kmax), corneal thickness, corneal elevation and corneal astigmatism.

The mean age of patients in the present study was 22.8 ± 6.4 years, with an age range of 12–42 years. The majority of patients belonged to the 21–30-year age group (45.2%), followed by the 16–20-year age group (31.0%). A male predominance was observed, with males constituting 61.3% of the study population. This young age distribution is consistent with the established epidemiological pattern of keratoconus, which commonly manifests during adolescence and young adulthood. Naderan et al. reported a mean age of 24 ± 7 years among 1081 patients with keratoconus, while an Indian tertiary eye-centre study reported a mean age of 20.1 ± 3.5 years.[7] The similarity between these findings and the present study suggests that keratoconus predominantly affects individuals during the active visual and occupational years of life.

The male predominance observed in the present study, with a male-to-female ratio of 1.58:1, was also comparable with findings from Indian studies. [8] Although the exact reasons for sex-related differences remain uncertain, variations in environmental exposure, eye-rubbing behaviour, healthcare-seeking patterns and possible hormonal influences have been proposed. Since the principal objective of the present study was to evaluate the relationship between clinical findings and corneal topography, sex-specific differences were not explored further.

In the present study, scissoring of the retinoscopic reflex was the most frequent clinical finding, being present in 87.0% of eyes, followed by corneal thinning in 76.0% and Fleischer ring in 64.0%. Vogt striaewere observed in 36.0%, Rizzuti sign in 29.0% and Munson sign in 18.0% of eyes. These findings emphasize the continued importance of detailed clinical examination in the diagnosis of keratoconus. Scissoring on retinoscopy reflects irregular corneal optics and may be present even before advanced structural changes become clinically obvious.

The frequency of Fleischer ring in the present study was lower than that reported in the Indian tertiary-centre study, where Fleischer ring was documented in approximately 81% of patients.[8] Such differences may be related to variations in disease severity, age distribution, duration of disease, referral patterns and the criteria used to document clinical signs. Nevertheless, both studies demonstrate that Fleischer ring is among the commonly encountered clinical manifestations of keratoconus.

The high frequency of scissoring reflex in the present study is clinically important. Li et al. incorporated clinical findings such as scissoring retinoscopy, corneal thinning, Vogt striae, Fleischer ring and Munson sign together with videokeratographic parameters in their classification of keratoconus. [9]

Their findings emphasized that topographic abnormalities may be evident even when clinical signs are minimal. This supports the use of corneal topography as an important adjunct to clinical examination, particularly in early or subtle disease.

The mean Kmax in our study was 55.18 ± 6.42 D, ranging from 45.10 to 72.40 D. Maximum keratometry represents the steepest measured corneal curvature and is one of the most commonly used quantitative indicators of corneal ectasia. In the present study, Kmax demonstrated significant associations with several clinically detectable manifestations of keratoconus.

Eyes with corneal thinning had significantly higher mean Kmax values than eyes without thinning. Similarly, higher Kmax values were observed among eyes with Fleischer ring, Vogt striae, Rizzuti sign, Munson sign and corneal scarring. The correlation between Kmax and these clinical signs was statistically significant. The strongest correlation was observed with Munson sign ($r=0.57$, $p<0.001$), followed by Rizzuti sign ($r=0.51$, $p<0.001$) and Vogt striae ($r=0.49$, $p<0.001$).

These observations are consistent with the findings of Schmitt et al., who evaluated 228 keratoconic eyes and demonstrated that maximum keratometry was the topographic parameter most strongly correlated with clinical manifestations.[9] They also reported significant correlations of SimKmax and mean power in the central 3-mm zone with clinical findings. The agreement between their observations and the present study supports the role of Kmax as an objective quantitative correlate of clinically apparent keratoconus.

The strong association of Munson sign with Kmax in the present study is particularly noteworthy. Munson sign is generally considered a manifestation of advanced corneal protrusion and is therefore expected to occur in eyes with marked corneal steepening. The substantially higher Kmax observed among eyes with Munson sign supports this relationship. Similarly, the association of Vogt striae and Rizzuti sign with higher Kmax indicates that these clinical signs reflect increasing structural deformation of the cornea.

A progressive increase in keratometric parameters was observed with increasing disease severity. Mean Kmax increased from 48.82 ± 2.34 D in mild disease to 54.26 ± 3.48 D in moderate disease and 63.42 ± 5.18 D in advanced/severe disease. This difference was statistically significant ($p<0.001$). Similar trends were observed for K1, K2 and corneal astigmatism.

These findings are consistent with the observations of Naderan et al., who evaluated 2073 eyes of 1081 patients and demonstrated significant changes in keratometric parameters with increasing keratoconus severity. [7] Their study showed that most topographic and keratometric parameters varied significantly between severity groups. The progressive increase in Kmax observed in the present study therefore provides further evidence that increasing corneal steepening is closely related to clinical disease severity.

Corneal thickness demonstrated an inverse relationship with disease severity. In the present study, mean thinnest corneal thickness decreased from 484.6 ± 27.8 µm in mild keratoconus to 452.4 ± 31.6 µm in moderate disease and 425.8 ± 37.4 µm in advanced/severe disease ($p<0.001$). Similarly, central corneal thickness decreased progressively across the severity groups.

This finding is in agreement with Naderan et al., who reported a significant reduction in central and thinnest corneal thickness with increasing disease severity.[7] Importantly, their study identified thinnest corneal thickness as one of the most important parameters for differentiating stages of keratoconus. The findings of our study therefore reinforce the importance of pachymetric assessment along with keratometric measurements when determining the severity of keratoconus.

The mean central corneal thickness in our study was 472.6 ± 39.8 µm and the mean thinnest corneal thickness was 454.8 ± 41.6 µm. Naderan et al. reported a mean central corneal thickness of approximately 462 ± 45 µm in their large cohort. [7] Although direct comparison is limited by differences in patient populations and imaging systems, the reduced corneal thickness observed in both studies is consistent with the characteristic structural changes of keratoconus.

The present study also demonstrated significant increases in anterior and posterior corneal elevation with increasing disease severity. Mean anterior elevation increased from 14.2 ± 5.8 µm in mild disease to 36.8 ± 12.6 µm in advanced/severe disease, whereas posterior elevation increased from 20.8 ± 7.2 µm to 44.6 ± 13.8 µm. These findings indicate that progressive keratoconus involves changes in both anterior and posterior corneal surfaces and that elevation-based parameters can provide additional information regarding the extent of ectatic deformation.

The importance of evaluating each eye separately was demonstrated by the bilateral but asymmetric nature of the disease. In the present study, 200 eyes from 168 patients were assessed individually. Chopra and Jain, in an Indian population, demonstrated significant inter-eye asymmetry in clinical, refractive and topographic parameters among patients with keratoconus. [10] They reported greater scissoring reflex, Munson sign, Vogt striae, corneal scarring and keratometric abnormalities in the more severely affected eyes. Their topographic analysis also demonstrated greater inferior-superior steepening and higher central and apex corneal powers in the worse eyes. [9]

An important observation from the study by Chopra and Jain was that some eyes that appeared clinically unaffected were found to have topographic evidence of keratoconus. [10] This finding highlights the importance of corneal topography in apparently unilateral or asymmetric disease. The results of the present study similarly support an eye-wise assessment rather than assuming equivalent disease severity in both eyes.

The visual and refractive findings in our study were consistent with the optical consequences of keratoconus. The mean unaided visual acuity was 0.48 ± 0.31 logMAR and improved to 0.18 ± 0.20 logMAR with best correction. The mean cylindrical refractive error was −3.18 ± 1.72 D, while mean keratometric astigmatism was 4.12 ± 2.11 D. The presence of substantial astigmatism reflects the irregularity of the corneal surface associated with keratoconus.

In the present study, BCVA demonstrated significant correlations with several topographic parameters. BCVA showed a positive correlation with Kmax ($r=0.48$, $p<0.001$), K2 ($r=0.41$, $p<0.001$), corneal astigmatism ($r=0.44$, $p<0.001$), anterior elevation ($r=0.32$, $p<0.001$) and posterior elevation ($r=0.35$, $p<0.001$). An inverse correlation was observed with thinnest corneal thickness ($r=-0.36$, $p<0.001$), suggesting poorer visual function with increasing corneal thinning.

These observations are broadly consistent with Bilen et al., who studied the relationship between visual function and refractive, topographic, pachymetric and aberrometric parameters in 71 keratoconic eyes. [11] They found significant associations between visual function and several topographic and aberrometric indices, particularly indices reflecting corneal irregularity. However, their study did not demonstrate a significant correlation between visual function and pachymetric parameters. [8] The difference may be related to differences in the imaging technology, severity distribution, visual function parameters and statistical methodology used in the two studies.

Bilen et al. also demonstrated that contrast sensitivity was more strongly affected than conventional corrected distance visual acuity and that indices such as the surface regularity index and irregular astigmatism index correlated significantly with contrast sensitivity. [8] In our study, only conventional visual acuity was assessed. Therefore, the significant correlation observed between BCVA and Kmax, K2 and corneal astigmatism suggest that conventional visual acuity is affected by increasing corneal irregularity, although assessment of contrast sensitivity and higher-order aberrations might provide additional information regarding visual quality.

Corneal astigmatism increased significantly with increasing severity in the present study, from 2.36 ± 0.82 D in mild disease to 6.42 ± 2.16 D in advanced/severe disease ($p<0.001$). This progressive increase reflects increasing irregularity of the corneal surface. Naderan et al. found that most parameters demonstrated significant associations with severity, although astigmatism did not show the same discriminatory value across all classification systems. [7] This difference indicates that astigmatism should preferably be interpreted together with Kmax, pachymetric and elevation parameters rather than used as an isolated indicator of disease severity.

The findings of the present study also support the complementary nature of clinical examination and corneal topography. Clinical examination allows recognition of characteristic signs such as scissoring reflex, corneal thinning, Fleischer ring, Vogt striae, Rizzuti sign and Munson sign. However, topography provides objective quantitative information regarding corneal curvature, elevation and thickness and may identify abnormalities before advanced clinical signs become evident. Li et al. demonstrated that videokeratographic parameters could identify early and suspect keratoconus even when clinical manifestations were limited.[9]

The clinical importance of early topographic detection is considerable because keratoconus is potentially progressive, particularly in younger patients. Identification of structural abnormalities at an early stage allows appropriate monitoring and may facilitate timely intervention in eyes demonstrating documented progression. Therefore, combining clinical examination with objective topographic parameters may provide a more comprehensive assessment than either approach alone.

Overall, the present study demonstrated a clear clinico-topographic relationship in keratoconus. Increasing clinical severity was associated with higher K1, K2 and Kmax values, greater corneal astigmatism and elevation, and lower central and thinnest corneal thickness. Clinical signs associated with more advanced disease, particularly Vogt striae, Rizzuti sign and Munson sign, were associated with higher Kmax values. These observations are consistent with previous studies demonstrating that quantitative topographic and pachymetric parameters reflect the structural and functional abnormalities of keratoconus.[7,8]

The findings have practical implications for ophthalmic practice. Clinical examination remains essential for diagnosis, but corneal topography provides objective information that can quantify the degree of corneal deformation, identify asymmetric or subclinical disease, assess severity and establish a baseline for subsequent follow-up. In particular, Kmax and thinnest corneal thickness appear to be useful parameters for correlating the clinical severity of keratoconus with objective structural changes.

Strengths of the Study

The present study included 200 eyes of 168 patients and evaluated a broad range of clinical, visual, refractive, topographic and pachymetric parameters. The simultaneous assessment of clinical signs and objective corneal measurements allowed a comprehensive evaluation of the relationship between clinical severity and corneal structural changes. The study was conducted at a tertiary ophthalmic centre, providing an opportunity to assess patients with different degrees of keratoconus severity.

Limitations of the Study

The study had certain limitations. Being a hospital-based observational study, selection bias could not be completely excluded, and the findings may not be directly generalizable to the general population. The 1.5-year study period limited assessment of longitudinal progression. Since both eyes of some patients were included, observations between fellow eyes were not completely independent; therefore, statistical analyses involving eye-level data should ideally account for clustering within patients. In addition, the study focused primarily on conventional clinical, topographic and pachymetric parameters, while biomechanical indices, higher-order aberrations and longitudinal progression indices were not evaluated.

Conclusion

The present study demonstrated a significant correlation between clinical manifestations and corneal topographic parameters in keratoconus. Increasing disease severity was associated with progressive corneal steepening, increased corneal astigmatism and elevation, and reduction in corneal thickness. Kmax showed particularly strong associations with clinically evident signs such as Vogt striae, Rizzuti sign and Munson sign. The findings support the use of corneal topography in conjunction with clinical examination for diagnosis and assessment of keratoconus severity. A combined clinical and topographic approach may facilitate earlier detection of subtle disease, accurate assessment of severity and appropriate monitoring of patients at risk of progression.

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