ORIGINAL ARTICLE

Prevalence of Keratoconus among Young Adults in Oman: A Cross-sectional Study Using Retinoscopy and Corneal Tomography

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Abstract

Objective: This cross-sectional study aimed to determine the prevalence of keratoconus (KC) among young individuals in the Omani population, covering the entire country. Additionally, the severity of keratoconus was investigated after detection of the disease.

Materials and methods: A total of 2750 participants were included in the study. The screening was conducted using retinoscopy (Phase 1) by well-trained optometrists, and those with a positive scissoring reflex underwent further assessment with corneal tomography to confirm the presence of keratoconus and assess its severity (Phase 2). Visual acuity and demographic data, such as age, sex, governorate, and village of residence, were collected during Phase 1, while corneal curvature parameters (K-Max, K-Mean, corneal thickness, back elevation) and keratoconus staging data were collected during Phase 2.

Results: Out of the 2750 participants screened, 184 individuals between the ages of 20 and 34 were found to have a positive scissoring reflex. Among them, 96 cases were confirmed to have keratoconus in one or both eyes through corneal tomography, regardless of the severity stage. This yielded a prevalence rate of 3.49% among the study population. Among the positive keratoconus cases, 38 were males and 58 were females, with only 15 individuals aware of their keratoconus condition. Analysis of positive cases revealed the highest prevalence in the Al Batinah North governorate. Severity analysis based on topographic keratoconus classification displayed five eyes in stage 3–4, indicating advanced disease. Additionally, 75 cases had corneal parameters suspected of keratoconus on corneal tomography but did not meet the diagnostic criteria (based on the KSS score, This system grades the severity of keratoconus from 0 (suspect) to 5 (severe) based on two corneal topographic indices (i.e., anterior corneal higher order aberration RMS error and mean central keratometry), and 13 cases were confirmed as false-positive scissoring reflex.

Conclusion: This study revealed a significant prevalence of keratoconus among young individuals in the Omani population. Compared with similar studies conducted in other parts of the world and neighboring countries, Oman appears to have a higher prevalence. Notably, a significant proportion of cases were already in advanced stages upon detection. Certain regions in Oman showed a higher prevalence, suggesting a potential relationship with geographic location and environmental factors. These findings warrant further investigation into the causative factors of keratoconus among the Omani population in the planned Phase 3 of the study. Close follow-up is recommended for cases suspected of having keratoconus but not meeting diagnostic criteria. Additionally, the lack of awareness among individuals with keratoconus, even in advanced stages, highlights the importance of population-based educational programs to promote early detection and intervention, ultimately preventing permanent visual disability.

Keywords: Keratoconus, Retinoscopy, Tomography.

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Introduction

Keratoconus (KC) is a progressive, non-inflammatory ectatic corneal disease that causes protrusion and thinning of cornea leading to irregular astigmatism and decreased visual acuity.[1] Generally, KC is a bilateral condition and majorly affects the inferior-central two-thirds of the cornea.[2] The KC usually occurs in adolescence and the disease progression extends to the age of 30 or 40.[3] KC is a multifactorial disease and environmental, genetic, and socioeconomic risk factors play a pivotal role in the disease progression. The important mediators of KC includes atopic diseases and eye rubbing, sunlight and UV-rays exposure, ethnicity, older age, parental consanguinity and positive family history.[4,5] The genes VXX114 and SOD1, about 1% mediate an important role in the pathogenesis of KC and autosomal dominant and sporadic pattern is the frequent pattern detected in familial KC.[6]

According to a recent systematic review and meta-analysis from 15 counties, the global prevalence of KC is estimated to be 1.4 per 1000.[7] The prevalence of KC is governed by various factors, such as demographics as well as diagnostic criteria and procedures employed. For example, the prevalence of KC in Russia is estimated as 0.3/100,000 and in Lebanon it is reported to be 3,300/ 100,000.[8,9] Various reports showed higher prevalence of KC in warmer regions like Middle East and Asian countries[10,11] as compared with Western regions with cold temperature.[2,8] Genetic susceptibility in various ethnic populations, precisely in individuals with tradition

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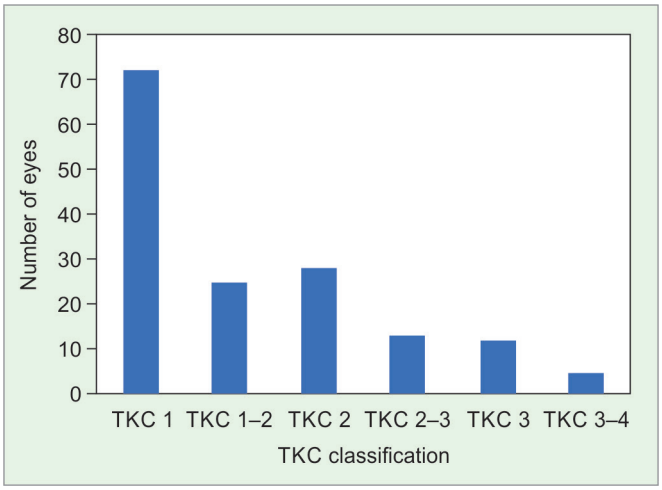

Fig.1: Distribution of KC-positive eyes (*n* = 155) according to Pentacam topographic keratoconus index (TKC)

of consanguinity has reported to have high prevalence of KC.[12] Studies have shown higher prevalence rates in certain ethnic groups, like Palestinians (Israeli Arabs) with an overall prevalence of 2340/100,000 including Jews,[13] non-Fars Iranian populations (3300/100,000),[14] Saudi Arabia (4.79%, 1:21 subjects),[15] Lebanese (3.3%)[9] as compared with Western population.[7] However, the accuracy of these estimates can be influenced by the inclusion of hospital-based studies, making it challenging to determine the true prevalence of the disease in the general population. These studies have contributed to our understanding of the prevalence rates of KC in different populations. However, there is a lack (lack of cross-sectional studies) of prevalence data specifically from the Middle East region (Fig. 1).

The objective of this study is to investigate the prevalence of keratoconus in the young Omani adult population across the entire country. By conducting a comprehensive assessment of keratoconus prevalence, this study aims to obtain more accurate and representative data on the burden of the condition. Furthermore, the study aims to assess the distribution of positive cases in each governorate (administrative region) of Oman, providing insights into the geographic variation of keratoconus prevalence.

By generating data specific to the local population, we can better understand the epidemiology of the disease and its impact on individuals in Oman. This knowledge is crucial for early detection and appropriate management such as corneal cross-linking (CXL) which is effective in mitigation of KC progression, enhances the mechanical rigidity of the cornea and avoid the need for corneal transplantation.[16,17] Additionally, the insights obtained from this study can help in public health initiatives aimed at raising awareness, improving access to care, and enhancing overall eye health in Oman.

Materials and Methods

Study Design and Participants

This cross-sectional study was conducted between January 2021 and March 2023 by the Ophthalmology Center of the MOD Hospital to determine the prevalence of keratoconus in the Omani population. The study population consisted of young adults aged 19–34 from Technical Colleges representing all regions in Oman. These colleges offer free education, transport, and accommodation, ensuring equal opportunities for all young Omanis to participate, regardless of their social, and economic status, or sex. As keratoconus primarily affects adolescents and young adults,[18] college students were selected as the screening population for the initial phase of the study.

As per the National Center for Statistics and Information (NCSI) data for the year 2021, young adults (18–29 age group) represent a total of 20.1% of the Omani population.

In 2019, a total of 35,000 students had been enrolled in all technical colleges in Oman.

Hence this 2750 student sample represents,

- 0.1% of the total population in Oman–2019
- 0.5% of the young population (Age 19–30) in Oman
- 7.8% of all students in the technical colleges
- Almost 1:1 Male to Female Ratio

From all these, we can infer that this sample represents the general young adult population in Oman.

Ethical clearance for the study was obtained from the ethical committee of the MOD-Hospital. All participants' confidentiality and privacy were strictly protected throughout the study.

Data Collection

The data collection process for this study consisted of two phases. In the first phase, a representative sample of subjects from all regions in Oman, encompassing various provinces (governorates) was selected. Suspected cases of keratoconus were identified using retinoscopy, a well-established method for detecting keratoconus and measuring refractive errors. Retinoscopy appears to be a very sensitive and reliable test for detecting keratoconus including early disease. Such a test may be implemented in population-based screening programs for keratoconus.[19]

The retinoscopy was done by a group of optometrists, qualified as optometry graduates and with more than 5 years of experience working in a cornea clinic.

In the second phase, the suspected cases identified during the initial screening were subjected to corneal tomography using a Pentacam HR machine.[20] Corneal tomography is known for its high sensitivity and specificity in diagnosing keratoconus.[21] The diagnosis of confirmed keratoconus and keratoconus suspects was made by two cornea specialists, ensuring accurate and reliable results.[21–23]

Demographic and Functional Parameters

Several variables and parameters were analyzed, including age, sex, governorate, maximum keratometry (K-Max), mean keratometry (K-Mean), thinnest pachymetry, back elevation.[24] Maximum keratometry represents the maximum curvature of the cornea and is crucial in diagnosing and characterizing keratoconus. Mean keratometry (K-Mean) provides additional information about corneal shape and potential irregularities associated with keratoconus. Thinnest pachymetry measures corneal thickness at its thinnest point, serving as an indicator for detecting and monitoring keratoconus progression. Back elevation assesses the posterior surface of the cornea during corneal tomography and helps differentiate keratoconus-positive cases from possible keratoconus cases (keratoconus suspects). Topographic Keratoconus Classification (TKC) provides detailed information about the extent and severity of keratoconus involvement, aiding in the diagnosis and characterization of the disease. Topographic Keratoconus Classification, namely, TKC 1, TKC 1–2, TKC 2, TKC 2–3, TKC 3, and

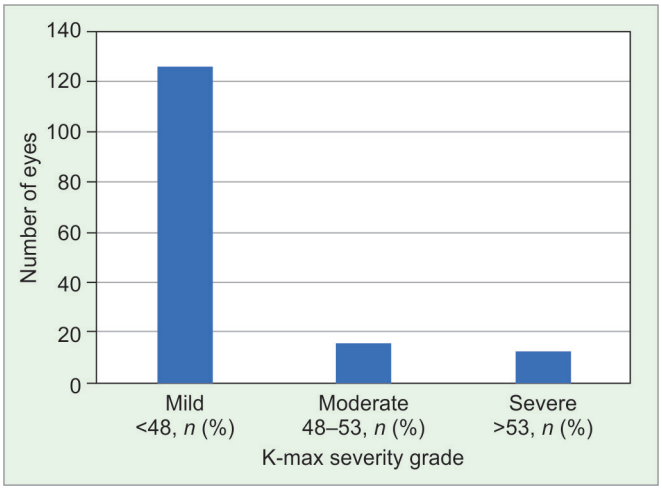

Fig. 2: Distribution of KC-positive eyes (*n* = 155) according to K-Max

TKC 3–4, is a specific grading system based on corneal tomography analysis.[25]

The administrative division of Oman contains Eleven Governorates (Provinces). The prevalence calculation involves counting the number of individuals who test positive for KC, regardless of the laterality and stage of the disease. Severity assessment in keratoconus refers to the evaluation of the extent of the disease in individual patients, taking into consideration the number of affected eyes (Fig. 2).

Instruments

The assessment of suspected individuals using a retinoscope was performed to measure refractive errors and detects keratoconus. A Pentacam HR machine was used for corneal tomography, providing three-dimensional images with a resolution of 25 images per scan.[26] The use of Pentacam in this study was based on its superior performance compared with other methods, as reported in the literature.[27]

Statistical Analysis

Means ± standard deviations (SD) were calculated to describe qualitative data, and proportions were calculated to describe quantitative data. The data was analyzed using Stata 16.1.

Results

The study population consisted of 2,750 individuals, and the demographic details of the study participants are given in Table 1. The mean age of the participants was 22.6 ± 1.9 years and male preponderance was observed accounting for 53.5% of the total sample. Regarding the governorates, majority of the participants were from Al Dhakiliya (19.82%), Muscat (16.54%), and Al Batinah North (14.57%), respectively.

Distribution of keratoconus among the scissoring positive cases is given in Table 2. Out of 2,750 participants, the diagnosis of KC was confirmed in 96 (3.5%) individuals either in one eye or both eyes. Out of these 96 individuals, 40 cases of unilateral (one eye) and 56 cases of bilateral (both eyes) involvement noted. Thirteen individuals (0.4%) were confirmed to not have keratoconus (No KC). Additionally, 75 individuals (2.7%) fell into the category of possible KC cases (KC suspects), warranting further evaluation or monitoring to determine their definitive diagnosis. These 75 cases had abnormal corneal surface parameters either in one eye or both eyes but did not meet the diagnostic criteria to label as keratoconus.

The demographic details of the KC-positive cases are given in Table 3.

Among the KC-positive cases, a total of 155 affected eyes were noted. The Pentacam TKC of KC affected eyes is given in Table 4. Out of 155 eyes, the majority of them were in TKC1 (72 eyes) followed by TKC 2 (28 eyes), and TKC 1–2 (25 eyes), respectively.

The clinical data of 155 KC eyes are given in Table 5. Visual acuity measurements showed an average uncorrected visual acuity (UCVA)

Table 1: Demographic details of the study participants

Patients demographics of the study participants	*N = 2,750*
Age, Mean (SD)	22.6 ± 1.9
Male, *n* (%)	1,471 (53.5)
Female, *n* (%)	1,279 (46.5)
Governorates	*N* = 11
Muscat	455 (16.54%)
Musandam	16 (0.58%)
Al Buraimi	57 (2.1%)
Al Batinah North	398 (14.47%)
AL Batina South	303 (11.01%)
Al Dahira	214 (7.78%)
Al Dhakiliya	545 (19.82%)
Al Shrqiya North	291 (10.58%)
Al Sharkiya South	143 (5.2%)
Al Wusta	10 (0.36%)
Dhofar	318 (11.56%)

Table 2: Distribution of KC among the scissoring positive cases

Scissoring reflex positive cases	*N = 184*
KC diagnosis	
KC-positive, *n* (%)	96 (3.49)
No KC, *n* (%)	13 (0.4)
Possible KC, *n* (%)	75 (2.7)

Table 3: Demographic details of the KC-positive cases

Patients demographics in KC-positive cases	*N = 96*
Age, Mean (SD)	22.57 ± 2.19
Male, *n* (%)	38 (39.6)
Female, *n* (%)	58 (60.4)
Unilateral KC-positive	40 (41.7)
Bilateral KC-positive	56 (58.3)

Table 4: Severity grading of the KC-positive eyes based on TKC classification

Pentacam topographic keratoconus classification (TKC)	*N = 155*
TKC 1	72
TKC 1–2	25
TKC 2	28
TKC 2–3	13
TKC 3	12
TKC 3–4	5

of 0.57 ± 0.3 and an average best-corrected visual acuity (BCVA) of 0.87 ± 0.2. Analysis of corneal measurements revealed mean values for K-Max of 47.31 ± 5.1 and K-Mean of 44.66 ± 3.4. The thinnest pachymetry measurement had a mean value of 498.7 ± 47.4.

The severity grading of KC based on K-Max (maximum corneal curvature) values is shown in Table 6. Out of 155 KC eyes, 81% of eyes were classified as mild (K-Max <48), 16% as moderate (K-Max between 48 and 53), and 8% as severe (K-Max > 53), respectively.

In the geographical distribution of KC, Al Batinah North governorate showed highest prevalence of KC. The results are given in Table 7 and the graphical data shown in Figure 3.

Discussion

The present study aimed to estimate the prevalence of KC in the Omani young adult population. Our findings revealed a 3.49% prevalence of Keratoconus among the young Omani population and Al Batinah North governorate showing the highest prevalence in terms of geographic location.

A recent systematic review reported the prevalence of keratoconus worldwide as 1.38 per 1000 population. The study analyzed 29 articles and included a total of 7,158,241 participants from 15 countries.[7]

A study conducted among children, adolescents and young adults in Saudi Arabia, found that prevalence of KC to be 4.8%.[15] Collectively, this evidence highlights the substantial impact of KC on the Middle-Eastern population and emphasizes the critical importance of early detection, accurate diagnosis, and appropriate management strategies for this condition.

In another study from the Netherlands, the prevalence of keratoconus in the general population was estimated to be 1:375 (265 cases per 100,000), according to the article.[28]

Another study estimated the prevalence and incidence of keratoconus in Denmark using data from the National Patient Registry. The prevalence was found to be 86 patients per 100,000 residents, and the incidence was estimated at 1.3 per 100,000 per year.[29]

A recently conducted study in Oman aimed to determine the effectiveness of retinoscopy as a screening tool for keratoconus. The researchers concluded that retinoscopy is a reliable and sensitive test for detecting keratoconus, including its early stages, and could be used in population-based screening programs for the disease.[19]

There is limited data on the prevalence and risk factors of keratoconus in Oman, and the available studies have reported conflicting results. A hospital-based study conducted between 2011 and 2015 found that there were 458 new keratoconus patients with a mean age of 20 years. The study concludes that a significant proportion of Omani keratoconus patients showed advanced disease on their first visit.[30]

This study highlights the need for accurate population-based prevalence data, which our study aimed to provide by covering the entire country. One notable finding from our study is the high

Table 5: Clinical parameters of KC-positive eyes (*n* = 155)

Clinical parameters	*KC eyes (n = 155)*
UCVA, Mean (SD)	0.57 ± 0.3
BCVA, Mean (SD)	0.87 ± 0.2
K-Max, Mean (SD)	47.31 ± 5.11
K-Mean, Mean (SD)	44.66 ± 3.44
Thinnest pachymetry, Mean (SD)	498.72 ± 47.41
Back elevation, Mean (SD)	26.17 ± 23.27

Table 6: Distribution of KC severity based on K-Max (maximum corneal curvature) values (*n* = 155)

Severity based on K-Max	*KC eyes (n = 155)*
Mild <48, *n* (%)	126 (81.3)
Moderate 48–53, *n* (%)	16 (10.3)
Severe >53, *n* (%)	13 (8.4)

Table 7: Prevalence of Keratoconus (KC) and probable KC by Governorate

Governorate		*KC-positive*	*KC suspect*
	Muscat	12 (6.5)	5 (2.7)
	Musandam	0 (0)	0
	Al Buraimi	0 (0)	2 (0.5)
	Al Batinah North	31 (16.8)	13 (10.2)
	AL Batina South	12 (6.5)	15 (2.7)
	Al Dahira	15 (8.2)	4 (2.2)
	Al Dhakiliya	9 (4.9)	7 (7)
	Al Shrqiya North	7 (3.8)	15 (2.7)
	Al Sharkiya South	2 (1.1)	0
	Al Wusta	0 (0)	0
	Dhofar	8 (4.3)	14 (2.2)

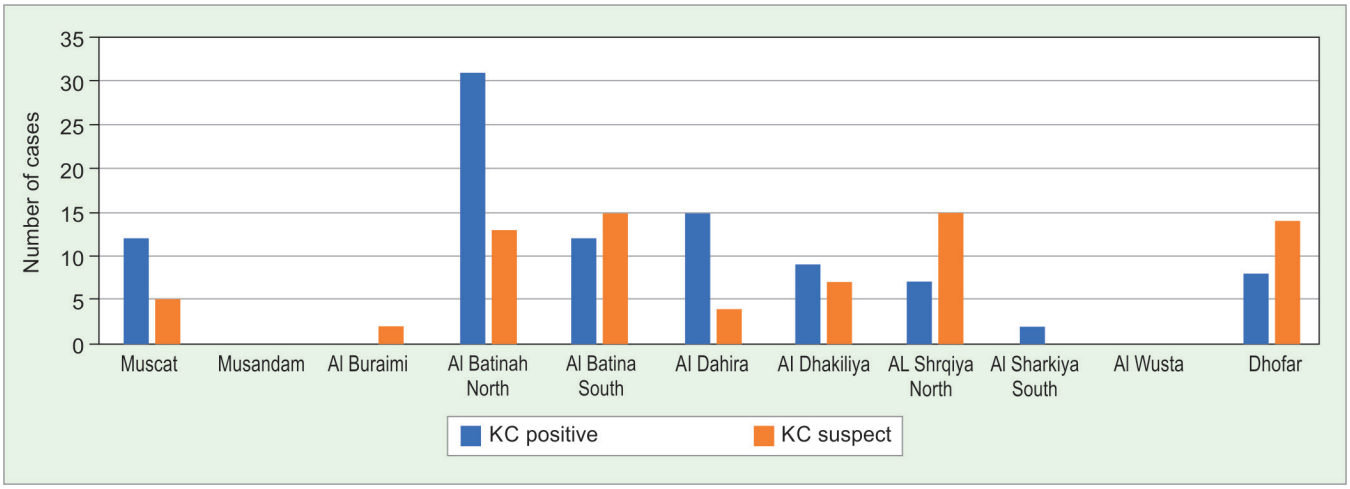

Fig. 3: Distribution of governorate among the KC-positive cases (*N* = 96)

number of KC suspects among the young adult population in Oman. This highlights the importance of proactive screening and diagnostic efforts to identify and diagnose cases at an early stage. Implementing screening programs and increasing awareness among healthcare professionals can aid in early detection and timely intervention, leading to better outcomes for individuals with KC.

In the context of our study, it is important to consider the severity of KC and its implications for disease management. Understanding the severity of KC is crucial for guiding treatment decisions and monitoring disease progression. Advanced stages of KC often require more aggressive interventions, such as CXL, intrastromal ring segment implantation, or even corneal transplantation, to prevent further deterioration of vision and maintain corneal stability. Identifying individuals with advanced KC at an early stage is vital to ensure timely and appropriate management to optimize visual outcomes and quality of life.

The strengths include the relatively large sample size covering all the regions and the rigorous study design. These factors enhance the reliability and generalizability of our findings. To our knowledge, this study is the first to encompass the entire population of Oman and provide a more accurate estimation of keratoconus prevalence on a population-based level. By including participants from various regions across the country, our study offers a comprehensive representation of the Omani population, enhancing the reliability and generalizability of our findings. Therefore, our study fills a critical gap in the existing literature by providing robust population-based prevalence data for the entire country of Oman.

However, certain limitations need to be considered. First, the study was conducted in a specific geographical area, which may limit the generalizability of the findings to other populations. Future studies involving diverse populations are necessary to validate our results. Potential confounding factors such as environmental exposures, genetic predispositions, or lifestyle factors were not extensively examined in this study and may have influenced the observed.

Conclusion

Our study provides valuable insights into the prevalence of keratoconus among young adults in Oman. The high prevalence observed in Al Batinah North governorate highlights the need for targeted interventions and awareness campaigns in these areas. Public health campaigns and educational initiatives targeting both healthcare professionals and the public can play a pivotal role in increasing awareness about KC, its risk factors, and the importance of regular eye examinations. By enhancing awareness, we can promote early detection, prompt referral for further evaluation, and appropriate management strategies, ultimately improving the overall prognosis and quality of life for individuals affected by keratoconus in Oman. Continued research efforts and collaborations are warranted to further investigate the risk factors and implications of keratoconus in the Omani population.

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