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Prevalence of refractive errors in Mexican patients with keratoconus

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Background: The purpose of this study was to determine the prevalence of refractive errors in Mexican patients with keratoconus (KCN) and to describe their clinical characteristics.

Methods: In this retrospective study, we reviewed the records of Mexican patients with KCN for the year 2012. Criteria for classifying refractive errors included the following: emmetropia –0.25 to +0.25 sphere, myopia >–0.25 sphere, hyperopia >+0.25 sphere, and astigmatism >–1.00 cylinder. Patient information was collected on refraction results, refractive diagnosis, slit-lamp examination, keratometry values, contact lens features, and best visual acuity with a contact lens. The prevalence of refractive errors was estimated by dividing the total number of eyes in the study by the number of refractive errors found.

Results: The study population comprised 426 patients, including 785 eyes with KCN. KCN was found more frequently in males (55.6%) than in females. The mean patient age was 28.1±10.3 years, and there was a greater frequency of moderate KCN. Compound myopic astigmatism had a prevalence of 87.3% and was present in all grades, although there are other types of refractive errors. The spherical rigid contact lens was the most frequently adapted lens (96%), and the contact lens parameters varied with disease progression.

Conclusion: The most common refractive error is compound myopic astigmatism, although there are many refractive errors that have not been described to date in the KCN population. The main lens used for correction is the spherical rigid contact lens. Finally, the parameters to adjust contact lenses change according to disease progression.

Keywords: keratoconus, visual acuity, refractive errors, rigid contact lens

Introduction

Ametropy is a refractive error caused by a defect in the curvature of the cornea, and it is widely known that abnormalities in this curvature are the major cause of vision defects. Within this context, keratoconus (KCN) is a bilateral and non-inflammatory corneal disease resulting in refractive error characterized by a gradual degeneration of the cornea that causes loss of visual function. The etiology of KCN is unknown, but environmental factors and a genetic predisposition contribute to development of the condition.[1–3] KCN affects approximately one in 2,000 individuals in the general population, and its onset is generally at puberty, with a variable amount of disease progression, which may last until the third or fourth decades of life, when the corneal shape generally becomes stable.[4,5] The reported prevalence is in the range of 8.8–229 per 100,000 individuals, with the mean age at onset being puberty.[5] In its early stages, KCN manifests as a subclinical condition, but in its later stages there is corneal edema and scarring, severely affecting quality of vision.[6] The disease is associated with irregular

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astigmatism, mainly of the myopic variety.[7] However, there are clinical cases of mixed astigmatism.

Accurate diagnosis of the type of astigmatism in patients with KCN is necessary for effective clinical intervention.[8] In the present study, we aimed to determine the prevalence of refractive errors in KCN in Mexican patients and their clinical characteristics.

Materials and methods

In this retrospective study, we reviewed the clinical charts of 426 patients, corresponding to 785 eyes with a diagnosis of KCN and with fitted contact lenses who were seen at the Instituto de Oftalmología Fundación de Asistencia Privada Conde de Valenciana IAP in Mexico City between January 2012 and December 2012 at the contact lens service. The protocols were approved either by the Local Research Committee or the National Ethical and Research Committees for the use of data in the present study. Criteria for a diagnosis of KCN were based on clinical findings from slit-lamp examination as described in the patients' clinical charts, including corneal thinning, Vogt's striae, conical protrusion of the apical cornea, Fleischer ring, and epithelial and subepithelial scarring or corneal topographic measurements. Classification of the grade of KCN was based on Buxton as mild (central K readings <45 D), moderate (central K readings 45–52 D), advanced (central K readings 52–62 D), or severe (central K readings >62 D), according to the guidelines of the Contact Lens Association of Ophthalmologists.[9] Inclusion criteria were: refractive correction, measures on the sphere, cylinder, and axis of refractive error; a refractive diagnosis; diagnosis of KCN, as previously described; keratometry values as corneal measurements using Helmholtz keratometer contact lens features: measurements of base curve, diameter, and refractive power; a spherical, toric, or multicurve design; and best visual acuity with contact lens as measured in Snellen decimals. These cases were included regardless of age and sex. Patients with a diagnosis other than KCN, those undergoing a surgical procedure as treatment, and those without a record of keratometry and/or refraction were excluded. Criteria for classifying refractive errors included emmetropia (−0.25 to +0.25) sphere, myopia >−0.25 sphere, hyperopia >+0.25 sphere, and astigmatism >−1.00 cylinder.

The prevalence of refractive errors was estimated by dividing the total number of eyes in the study by the number of refractive errors found. The reported refractive errors were those presented in all of the cases, while those that were not mentioned were excluded from the report.

Statistical analysis

Differences in the prevalence of refractive error for each group (mild, moderate, advanced, and severe) were assessed by contingency tables. The chi-square test was used, and the results were taken to be statistically significant at a level of $P<0.05$. The prevalence of type-specific refractive error was compared with the 95% confidence interval. The statistical analysis was performed using Statistical Package for the Social Sciences version 15 software (SPSS Inc., Chicago, IL, USA).

Results

The study population comprised 426 patients, corresponding to 785 eyes; 55.6% of the patients were male. The mean patient age was 28.14±10.30 (range: 10–75) years; the age range for males was 10–75 years and for females was 11–63 years. Table 1 shows the distribution of diagnosis of KCN according to age and sex. KCN was more frequent in males (55.8%) overall, and in both males and females in the second and the third decades of life (25.1% and 39.1%, respectively).

Distribution of the diagnosis of KCN for all eyes by grade and sex shows a high frequency of moderate (45.9%) and mild (36.4%) stages in both males and females (Table 2). Mild and moderate grades were more frequent in the second and third decades of life, while a moderate grade of KCN was most common in the fourth decade of life (11.2%). Neither advanced nor severe grades were found in patients aged older than 60 years (Table 3).

Next, we calculated the prevalence of refractive errors by sex (Table 4), and found that compound myopic astigmatism was the most frequent refractive error in eyes with KCN, being present in 87.5% of eyes. With-the-rule compound myopic astigmatism was present in 56.5% of all cases and was more common in males, followed by against-the-rule compound myopic astigmatism (15.7%, with a greater frequency in females) and oblique compound

Table 1 Distribution of patients with keratoconus by age and sex

Age (years)	Male % (n)	Female % (n)	Total % (n)
10–20	18.7 (80)	6.3 (27)	25.1 (107)
21–30	20.1 (86)	19 (81)	39.2 (167)
31–40	11.2 (48)	11.5 (49)	22.7 (97)
41–50	3.9 (17)	4.4 (19)	8.4 (36)
51–60	0.4 (2)	1.8 (8)	2.3 (10)
>60	0.2 (1)	0.4 (2)	0.7 (3)
Total	55.8 (237)	43.6 (189)	100 (426)

Table 2 Distribution of patients by sex and grade of keratoconus

Grade	Male % (n)	Female % (n)	Total % (n)
Mild	19.3 (152)	17 (134)	36.4 (286)
Moderate	24.5 (193)	21.4 (168)	45.9 (361)
Advanced	7.2 (57)	4.9 (39)	12.2 (96)
Severe	3.6 (29)	1.6 (13)	5.3 (42)
Total	54.9 (431)	45 (354)	100 (785)

myopic astigmatism (15.3%). With-the-rule simple myopic astigmatism was present in 4.3% of cases, followed by with-the-rule mixed astigmatism at 2.8%. Against-the-rule mixed astigmatism was present in 1.9% and against-the-rule simple myopic astigmatism in 1.2%, the latter present in females. Myopia was present in 0.8% and oblique simple myopic astigmatism in 0.6%. Oblique mixed astigmatism was found in 0.3%, but only in men. Finally, against-the-rule compound hyperopic astigmatism, against-the-rule simple hyperopic astigmatism, and hyperopia were found to be 0.1% for each.

The refractive errors were also classified according to KCN grade. In eyes with mild KCN, three refractive errors were more frequent, and are presented here in descending order as follows: with-the-rule compound myopic astigmatism in 17.8% of eyes; oblique compound myopic astigmatism in 5.6% of eyes; and against-the-rule compound myopic astigmatism in 4.5% of eyes. Against-the-rule simple hyperopic astigmatism was not observed (Table 5). In eyes with moderate KCN, we found the first three previously mentioned refractive errors, but with different percentages, ie, with-the-rule compound myopic astigmatism was present in 27.5% of all eyes, against-the-rule compound myopic astigmatism in 7.6%, and oblique compound myopic astigmatism in 6.7%. Nearly all refractive errors were present with this grade, except for against-the-rule compound hyperopic astigmatism, oblique simple myopic astigmatism, and hyperopia. In advanced and severe stages, the three previously mentioned refractive errors remained the most frequent alterations, and myopia was present in the advanced stage, but no other refractive errors were observed at either stage. As can be seen, the more frequent refractive errors in patients with KCN were with-the-rule compound myopic astigmatism in 56.5%, against-the-rule compound myopic astigmatism in 15.7%, and oblique compound myopic astigmatism in 5.3%.

The rigid contact lens is the main method used to correct KCN. Our results show that the spherical rigid contact lens was the main type of lens used for correction, being used in 96% of eyes, followed by the multicurve rigid contact lens and the toric rigid contact lens (Table 6). Adaptation of the contact lens parameters was specific for each case. Table 7 shows the mean value for each adaptation parameter in the different stages of KCN. The lens base curve decreased with progression of KCN: the mean value for mild grade disease was 7.79±0.29 mm, 7.30±0.35 mm for moderate grade, 6.80±0.34 mm for advanced grade, and 6.34±0.40 mm for severe grade. The lens diameter values were similar in the different stages, but these also showed a reduction, with means of 9.0±0.22, 8.9±0.24, 8.7±0.27, and 8.6±0.23, according to stage of disease. Refractive power decreased on progression through to advanced stages of KCN, ie, from −2.50±3.36 in mild grade to −13.15±5.39 in severe grade. Mean best visual acuity with contact lenses decreased from 0.81±0.19 in the mild stage to 0.45±0.21 in the advanced stage. After fitting of contact lenses, we arrived at a new diagnosis, divided among ametropia, hyperopia, and myopia; in the latter is concentrated 85.8% of eyes (Table 8).

Discussion

The etiology of KCN is unclear, but a strong genetic component has been suggested.[2,3] The condition is usually associated with different variants of astigmatism, in particular myopic astigmatism.[5,6] On reviewing the literature, it is evident that a relationship exists between KCN and astigmatism.[10] Intriguingly, we did not find published data on other astigmatism variants, such as mixed astigmatism. The prevalence of KCN ranges from approximately 0.05 to 0.6, because of the different definitions and diagnostic criteria used.[11] On the other hand, the frequency of refractive errors is high, ie, these errors are present in >50% of

Table 3 Distribution of total eyes by keratoconus grade and decade of life

Grade	Age 10–20 years % (n)	Age 21–30 years % (n)	Age 31–40 years % (n)	Age 41–60 years % (n)	Age >60 years % (n)	Total % (n)
Mild	8.6 (68)	17.3 (136)	7.3 (58)	2.9 (23)	0.1 (1)	36.4 (286)
Moderate	11.8 (93)	17.3 (136)	11.2 (88)	5.2 (41)	0.3 (3)	45.9 (361)
Advanced	2.6 (21)	3.1 (25)	3.4 (27)	2.9 (23)	0	12.2 (96)
Severe	1.2 (10)	1.7 (14)	1.4 (11)	0.8 (7)	0	5.3 (42)
Total	24.4 (192)	39.6 (311)	23.4 (184)	11.9 (94)	0.5 (4)	100 (785)

Table 4 Prevalence of refractive errors in keratoconus eyes by sex

Refractive error	Male % (n)	Female % (n)	Total % (n)
Against-the-rule compound hyperopic astigmatism	0.1 (1)	0	0.1 (1)
Against-the-rule simple hyperopic astigmatism	0	0.1 (1)	0.1 (1)
With-the-rule compound myopic astigmatism	32.8 (258)	23.6 (186)	56.5 (444)
Oblique compound myopic astigmatism	7.1 (56)	7.8 (62)	15.3 (118)
Against-the-rule compound myopic astigmatism	7.6 (60)	8.1 (64)	15.7 (124)
With the rule mixed astigmatism	2.1 (17)	0.6 (5)	2.8 (22)
Oblique mixed astigmatism	0.3 (3)	0	0.3 (3)
Against-the-rule mixed astigmatism	0.8 (7)	1 (8)	1.9 (15)
With-the-rule simple myopic astigmatism	2.4 (19)	1.9 (15)	4.3 (34)
Oblique simple myopic astigmatism	0.3 (3)	0.2 (2)	0.6 (5)
Against-the-rule simple myopic astigmatism	0.3 (3)	0.8 (7)	1.2 (10)
Hyperopia	0	0.1 (1)	0.1 (1)
Myopia	0.5 (4)	0.3 (3)	0.8 (7)
Total	54.9 (431)	45 (354)	100 (785)

people aged older than 40 years, and are the main cause of low vision.[12] KCN is usually accompanied by astigmatism, a type of refractive error, which changes with progression of the disease.[13] There is a considerable number of studies describing the prevalence and types of KCN, but there is insufficient information about the prevalence of refractive errors in this disease in some countries.[5] Knowledge of the type of refractive error could assist in staging KCN, although this is not the sole criterion. Crews et al found that patients with KCN had the best correction with contact lenses,[14] but this adaptation depended on corneal curvature and type of astigmatism. The goal was to determine the prevalence of refractive errors in order to assist the patient with their visual acuity.

In this study, we retrospectively reviewed the records of 426 patients (237 males and 189 females) with a mean age of 28.1 years at diagnosis. It is noteworthy that few cases were in the population aged older than 40 years, as in the studies of Losada and Mahadevan.[18,19] Our study showed a slight predominance of male sex in the second and third decades of life, as demonstrated in previous studies,[15] although some reports shows a slight predominance of women.[16] The main stages of the disease were moderate or mild in both males and females.

Li et al found KCN to be the most common corneal disease in patients aged 10–19 years, with a prevalence of 21.2%,[17] and the main method for correcting low vision to be contact lenses, indicating the importance of knowing the refractive error in order for clinical intervention to be effective.

A recent study of 93 Mexican patients with KCN (Lara et al, unpublished data, 2014) found a high frequency of myopic astigmatism (87%) and a low frequency of mixed astigmatism (7.5%).

When we attempted to compare our refractive error rates with those of other researchers, we found very few relevant

Table 5 Classification of refractive errors by keratoconus grade

Refractive error	Mild % (n)	Moderate % (n)	Advanced % (n)	Severe % (n)	Total % (n)	*P*-value
CHA ar	0.1 (1)	0	0	0	0.1 (1)	0.619
SHA ar	0	0.1 (1)	0	0	0.1 (1)	0.619
CMA wr	17.8 (140)	27.5 (216)	7.1 (56)	4 (32)	56.5 (444)	0.086
CMA o	5.6 (44)	6.7 (53)	1.9 (15)	0.7 (6)	15.3 (118)	0.992
CMA ar	4.5 (36)	7.6 (60)	3 (24)	0.5 (4)	15.7 (124)	0.040*
MXA wr	1.7 (14)	1 (8)	0	0	2.8 (22)	0.034*
MXA o	0.2 (2)	0.1 (1)	0	0	0.3 (3)	0.689
MXA ar	1.4 (11)	0.5 (4)	0	0	1.9 (15)	0.022*
SMA wr	3 (24)	1.2 (10)	0	0	4.3 (34)	0.000*
SMA o	0.6 (5)	0	0	0	0.6 (5)	0.033*
SMA ar	0.6 (5)	0.6 (5)	0	0	1.2 (10)	0.512
H	0.1 (1)	0	0	0	0.1 (1)	0.619
M	0.3 (3)	0.3 (3)	0.1 (1)	0	0.8 (7)	0.927
Total	36.4 (286)	45.9 (361)	12.2 (96)	5.3 (42)	100 (785)	

Notes: *χ^2 test. Statistically significant.

Abbreviations: CHA ar, compound hyperopic astigmatism against the rule; SHA ar, simple hyperopic astigmatism against the rule; CMA wr, compound myopic astigmatism with the rule; CMA o, compound myopic astigmatism oblique; CMA ar, compound myopic astigmatism against the rule; CMA ar, compound myopic astigmatism against the rule; MXA wr, mixed astigmatism with the rule; MXA o, mixed astigmatism oblique; MXA ar, mixed astigmatism against the rule; SMA wr, simple myopic astigmatism with the rule; SMA o, simple myopic astigmatism oblique; SMA ar, simple myopic astigmatism against the rule; H, hyperopia; M, myopia.

Table 6 Type of contact lens adaptation in patients with keratoconus

Lens type	Adaptations % (n)
Spherical rigid contact lens	96 (754)
Multicurve rigid contact lens	3.1 (25)
Toric rigid contact lens	0.7 (6)
Total	100 (785)

studies. Lara et al found refractive error frequencies in KCN eyes that were very similar to ours; they also found compound myopic astigmatism in 87%, simple myopic astigmatism in 5.3%, and mixed astigmatism in 7.5% (unpublished data) of eyes. In our study, compound myopic astigmatism was present in all grades of disease, but was more frequent in moderate grade disease, while mixed astigmatism and simple myopic astigmatism were found in mild grade disease, perhaps because the corneal curve was close to emmetropia (43.25 D, or 7.8 mm), although is not the only parameter responsible for the refractive error. Myopia was observed in all grades of KCN except for the severe stage.

Principal refractive correction involves use of contact lenses. In a study reported by Mahadevan et al, 83% of adaptations were rigid gas permeable contact lenses, 4.6% were rigid contact lenses, 8.4% were piggy back contact lenses, and 1.9% were sclera contact lenses, with 1.9% of subjects undergoing surgery.[18] Meanwhile, Losada et al reported that 89.4% of their subjects were wearing rigid gas permeable contact lenses, 8.7% wore soft contact lenses, and the lens could not be adapted in 1.7% of cases.[19] In this study, as in others, the spherical lens is the most common lens used for correcting refractive error. We did not find the use of soft contact lenses, probably because of their contraindications, such as low shape perception, progress of KCN, and the high risk of corneal edema. With this type of correction, patients with mild or moderate KCN and contact lenses achieve a best visual acuity of 0.81±0.19 and 0.77±0.20, respectively, and these patients are the best candidates for correction with the spherical rigid contact lens.

Table 7 Parameters of contact lenses according to keratoconus grade

Grade	Lens base curve (mm)	Diameter (mm)	Power (D)	BVA with contact lens, Snellen decimal
Mild	7.79±0.29	9.0±0.22	–2.50±3.36	0.81±0.19
Moderate	7.30±0.35	8.9±0.24	–4.66±4.37	0.77±0.20
Advanced	6.80±0.34	8.7±0.27	–8.51±5.09	0.64±0.20
Severe	6.34±0.40	8.6±0.23	–13.15±5.39	0.45±0.21

Abbreviation: BVA, best visual acuity.

Table 8 Percent of adaptations with a new diagnosis after corrected visual acuity

Diagnosis with contact lens correction	Adaptations % (n)
Emmetropia	5.9 (47)
Hyperopia	8.1 (64)
Myopia	85.8 (674)

Finally, we report the mean values for the parameters used to adjust the lenses according to KCN grade for rigid gas permeable contact lens fitting. The mean base curve was 5.1–8.5 mm, the lens diameter was 7.9–9.6 mm, and best visual acuity with the contact lens was 0.05–1 (20/400–20/20). Lens base curve, diameter, and best visual acuity with the contact lens decreased with progression of KCN grade; additionally, the (+2.75 D to –28.25 D) negative power increased with progression of the disease, perhaps because of the increase in the corneal curve due to disease progression and the decrease in diameter, which conferred better lens stability. These parameters have already been reported,[19] but Mahadevan et al showed that the base curves and diameter decreased.[18] The parameters used to adjust the contact lenses change as the disease progresses.

Conclusion

The prevalence of refractive errors and the values for adaptation parameters are similar to those in previous reports. We found with-the-rule compound myopic astigmatism to be the most common refractive error, followed by against-the-rule compound myopic astigmatism and oblique compound myopic astigmatism. Further, the rigid gas permeable lens was most common lens worn, and the parameters used for adaptation of the contact lens changed with progression of the disease. This study contributes to a better understanding of KCN and how to achieve the best visual correction for patients with the disease.

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Disclosure

The authors report no conflicts of interest in this work.

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