Clinical Ophthalmology

Dovepress
open access to scientific and medical research

Open Access Full Text Article

ORIGINAL RESEARCH

A Comparison of Black and Non-Black Patients in the Presentation and Treatment of Keratoconus

Michael Christensen[1], Jeffrey Kartchner[1–3], Matthew Giegengack[1,2,*], Atalie C Thompson[1,2,4,*]

[1]Wake Forest University School of Medicine, Winston Salem, NC, USA; [2]Department of Surgical Ophthalmology, Atrium Health Wake Forest Baptist Medical Center, Winston Salem, NC, USA; [3]Arizona Eye Consultants, Tucson, AZ, USA; [4]Department of Gerontology and Geriatric Medicine, Atrium Health Wake Forest Baptist Medical Center, Winston Salem, NC, USA

*These authors contributed equally to this work

Correspondence: Michael Christensen, Wake Forest University School of Medicine, 475 Vine St, Winston Salem, NC, 27101, USA, Tel +1-707-880-7802, Email mchriste@wakehealth.edu

Purpose: Patients with advanced keratoconus (KCN) are less likely to benefit from corneal cross-linking and may require a partial or full thickness keratoplasty. This study aimed to determine whether racial disparities exist in the clinical presentation and initial treatment recommendations for patients evaluated for KCN.

Methods: A single-center retrospective review was conducted on all patients who presented to the cornea department for initial evaluation of KCN between 2018 and 2020. Patients who had undergone prior corneal procedures or surgeries were excluded. Baseline sociodemographic and clinical information was collected and stratified according to black versus non-black race. Generalized estimating equations were used to examine the association between black race and presenting corrected distance visual acuity (CDVA), presence of corneal scarring, keratometry values, Belin ABCD score, and treatment recommendations. Multivariate models were adjusted for patient demographics.

Results: A total of 128 patients (251 eyes) were included in this study. In fully adjusted models, black individuals presented with significantly worse CDVA ($p < 0.0001$) and worse tomographic KCN staging according to the Belin ABCD criteria ($p = 0.002$) compared to non-blacks. Blacks were also more than four times as likely to present with a thinnest pachymetry <400 µm ($p < 0.0001$) and more than three times as likely to have corneal scarring ($p = 0.001$). Blacks were more than seven times more likely to have keratoplasty recommended as treatment than conservative management such as corneal cross-linking or contact lenses ($p = 0.004$).

Conclusion: Compared with their non-black counterparts, blacks presented with significantly more advanced KCN, which placed them at risk of requiring more invasive treatment plans. Future studies should investigate reasons for such late presentations and aim to mitigate disparities in the presentation and management of KCN.

Keywords: corneal cross-linking, corneal transplant, racism in ophthalmology, Cornea

Introduction

Keratoconus (KCN) is a corneal ectatic disease with an annual incidence of 2.0 per 100,000 individuals and a prevalence of 54.5 per 100,000 individuals.[1] Eye rubbing, allergies, asthma, sleep apnea, positive family history, and connective tissue disorders are some common risk factors known to increase KCN prevalence and affect disease severity.[2,3] Patients who present with signs of advanced KCN, such as severe corneal thinning and scarring, are more likely to undergo corneal transplantation via deep anterior lamellar keratoplasty (DALK) or penetrating keratoplasty (PKP).[4] However, if KCN is detected at an earlier stage, patients may be able to benefit from newer, less invasive therapies such as corneal collagen cross-linking (CXL). CXL has been shown to prevent progression of mild disease and improve patient outcomes,[5] but it is contraindicated in patients with severe corneal thinning and/or scarring.[6]

Many factors can influence late presentation for treatment, including social determinants of health such as socioeconomic status (SES)[7] and access to health insurance.[8] Moreover, disparities in treatment have been shown to disproportionately affect those of black or African American race across many fields of medicine.[9–14] In ophthalmology, blacks demonstrate

Received: 4 November 2023
Accepted: 15 January 2024
Published: 26 January 2024

a disproportionately greater burden of disease for multiple eye diseases such as diabetic retinopathy,[15] optic neuritis,[16] and glaucoma.[17,18] Such late presentations can lead to more invasive and riskier treatment recommendations.

In this study, we investigated whether black individuals were more likely to present with evidence of advanced KCN than non-blacks and whether this was related to more invasive treatment recommendations such as surgical keratoplasty rather than conservative management with CXL or contact lenses (CL).

Materials and Methods

This study was a single-center retrospective review of all consecutive patients who presented to the cornea department of a tertiary referral center for a new KCN evaluation between January 1, 2018, and December 31, 2020. Patients who had undergone prior corneal surgery or CXL were excluded. The Institutional Review Board of Atrium Health Wake Forest Baptist approved this study with a waiver of informed consent due to its retrospective nature. Data collection and reporting were conducted in compliance with all Health Insurance Portability and Accountability Act regulations, and research was conducted in accordance with the Declaration of Helsinki.

Demographic information including age, sex, race (black vs non-black), and insurance status (none vs public [Medicare, Medicaid, or Veteran Affairs] vs private) was collected from the electronic health record. The cornea provider, referral source (self-referral vs optometrist vs physician), and prior treatment with glasses or CL were also recorded.

Corrected distance visual acuity (CDVA) was converted to the logarithm of the minimum angle of resolution (logMAR) CDVA score for statistical analysis. Corneal scarring was noted on the initial slit-lamp examination. Keratometry measurements were taken using Oculus Pentacam imaging (OCULUS Optikgeräte GmbH, Wetzlar, Germany), which measured the keratometric steepest corneal radius (Steepest K), anterior and posterior radii of curvature (ARC and PRC, respectively), and thinnest pachymetry. The latter three values, combined with the CDVA score, were used to calculate Belin ABCD scores,[19] a scoring classification used for KCN staging. A variable for the thinnest pachymetry measurement <400 μm vs ≥400 μm was also created because prior studies have indicated that this is the minimum corneal thickness required for effective CXL.[20,21] Consequently, those with the thinnest pachymetry measurement <400 μm are more likely to be recommended for keratoplasty.

Finally, the corneal specialist's initial treatment plan for keratoplasty (ie, DALK and PKP) or other (scleral CL evaluation, glasses, CXL, etc) based on presentation was documented.

Statistical Analyses

Baseline patient-level sociodemographic and clinical variables (race, age, sex, insurance status, referral source, treating provider, and prior treatment) were examined using *t*-tests for continuous variables and chi-squared tests for categorical variables. Separate generalized estimating equations (GEE) with an exchangeable matrix correlation to account for the inter-eye correlation were constructed to describe the baseline association of race and each potentially confounding sociodemographic or clinical variable with presenting clinical characteristics related to KCN severity, including (1) initial keratometry values (ARC, PRC, steepest K, thinnest pachymetry) and ABCD score, (2) logMAR CDVA score, (3) thinnest pachymetry measurement <400 μm, (4) corneal scarring at presentation, and (5) initial treatment recommendation. First, unadjusted (ie, bivariate) analyses were performed, and then subsequent adjusted multivariable models were constructed, including all covariates (ie, black race, age, sex, insurance type, referral source, prior treatment with glasses or CL, and cornea provider). To determine whether the association between black race and logMAR CDVA, corneal scarring, and initial treatment recommendations was related to thinner corneas, having a thinnest pachymetry <400 μm was entered in final exploratory models as a covariate and as an interaction term. Statistical analyses were performed using Stata (vs 17.1, Stata Corp, College Station, TX). Statistical significance was set at $p < 0.05$.

Results

This study included 128 patients (251 eyes). Of these, 66 (51.6%) patients identified as white, 46 (35.9%) as black or African American, 13 (10.2%) identified as Hispanic or Latino, and three (2.3%) identified as other races or ethnicities. The remainder of patient demographics are listed in Table 1. Black patients were more likely to be female ($p = 0.031$).

Table 1 Patient Demographic and Clinical Characteristics at Presentation Stratified by Black Race

Demographics	Black (n=46 People)	Non-Black (n=82 people)	p-value
Mean age ± SD at presentation (years)	34.8 ± 10.5	34.2 ± 14.7	0.804
Sex, n (%) Female Male	 21 (45.7) 25 (54.3)	 22 (26.8) 60 (73.2)	 0.031*
Insurance status, n (%) Public/VA None Private	 14 (30.4) 3 (6.5) 29 (63.0)	 11 (13.4) 5 (6.1) 66 (80.5)	 0.061
Referring provider, n (%) MD OD Self-referral	 20 (43.5) 20 (43.5) 6 (13.0)	 28 (34.1) 36 (43.9) 18 (22.0)	 0.380
Prior treatment, n (%) Glasses/none Contact lenses	 27 (58.7) 19 (41.3)	 41 (50.0) 41 (50.0)	 0.344
Cornea provider, n (%) Provider 1 Other provider	 27 (58.7) 19 (41.3)	 45 (54.9) 37 (45.1)	 0.676

Notes: P-values from *t*-test for continuous variables and chi-square test for categorical variables. *Statistically significant value.
Abbreviations: MD, physician-referred; OD, optometrist-referred; SD, standard deviation; VA, veteran affairs.

Black eyes presented with more advanced KCN disease by every keratometry measure including ARC, PRC, steepest K, and thinnest pachymetry, as well as ABCD score (all $p < 0.0001$). However, black race only remained significantly associated with thinner pachymetry ($p = 0.002$) and worse (higher) ABCD scores ($p = 0.002$) in the final multivariable models which adjusted for other covariates (Table 2). Black eyes were approximately four times more likely to present with a thinnest pachymetry <400 µm

Table 2 The Association of Black Race with Keratometry Measurements at Presentation

Race	ARC	PRC	Steepest K	Thinnest Pachymetry	ABCD Score[a]
Mean keratometry values ± Standard Deviation (SD)					
Black mean ± SD	5.90 mm ± 0.99	4.33 mm ± 0.92	58.96 D ± 11.55	403.59 µm ± 67.40	11.94 ± 3.3
Non-black mean ± SD	6.53 mm ± 0.85	4.89 mm ± 0.82	51.55 D ± 7.59	453.11 µm ± 69.50	9.33 ± 3.79
Unadjusted Beta Coefficient (95% CI), p-value					
Black vs non-black	−0.62 (−0.89, −0.36), p<0.0001*	−0.55 (−0.80, −0.30), p<0.0001*	7.43 (4.72, 10.1), p<0.0001*	−49.27 (−70.83, −27.72), p<0.0001*	2.61 (1.64, 3.59), p<0.0001*
Adjusted Beta Coefficient (95% CI), p-value					
Black vs non-black	−0.16 (−0.41, 0.10), p=0.222	−0.19 (−0.43, 0.05), p=0.128	1.56 (−0.65, 3.78), p=0.167	−24.77 (−40.13, −9.42), p=0.002*	1.56 (0.60, 2.53), p=0.002*

Notes: Bivariate unadjusted generalized estimating equations (GEE) were between race (independent variable) and keratometry values (dependent variable). Multivariable adjusted GEE included race, age, sex, insurance type, referring provider, treating cornea specialist, and prior treatment with glasses/contact lenses. *Statistically significant values. [a]ABCD score is calculated using ARC, PRC, steepest K, and corrected distance visual acuity. A higher score indicates more progressed keratoconus disease.
Abbreviations: ARC, Anterior Radius of Curvature; PRC, Posterior Radius of Curvature; SD, standard deviation; Steepest K, steepest corneal radius.

in both unadjusted and fully adjusted models [adjusted odds ratio (OR) 4.40, 95% CI (2.00, 9.67), p < 0.0001] (Table 3). In addition, they were more than three times more likely to present with corneal scarring on examination, and this remained significant in adjusted analyses [OR 3.43, 95% CI (1.61, 7.31), p = 0.001] (Table 4).

Blacks were more likely to have worse (higher) logMAR CDVA scores in both unadjusted and adjusted models (p < 0.0001) (Supplemental Table 1). The average logMAR CDVA score for black eyes was 0.63 ± 0.52 (a Snellen equivalent of approximately 20/85, n = 92 eyes), while non-black eyes had a mean of 0.33 ± 0.36 (a Snellen equivalent of approximately 20/43, n = 159 eyes). Patients with public/veteran affairs (VA) insurance were also significantly more likely to have worse (higher) logMAR CDVA scores than those with private insurance [Beta coefficient 0.22, 95% CI (0.08, 0.36), p = 0.002]. Referral by an optometrist was associated with a better (lower) logMAR CDVA score than referral by a physician (beta coefficient −0.13, 95% CI [−0.25, −0.003], p = 0.045).

In terms of initial treatment recommendation, blacks were more than seven times more likely to have keratoplasty recommended based on initial evaluation [OR 7.75, 95% CI (1.89, 31.75), p = 0.004] (Table 5). Ten (10.9%) black eyes were recommended DALK or PKP compared to only three (1.9%) non-black eyes. The other treatments category included CXL, CL, and other interventions (ie, glasses, close follow-up). For these treatment options, 13 (14.1%) black eyes and 57 (35.8%) non-black eyes were recommended CXL, 57 (62.0%) black eyes and 80 (50.3%) non-black eyes were recommended CL, and 12 (13.0%) black eyes and 19 (11.9%) non-black eyes were recommended another non-surgical intervention (ie, glasses, close follow-up).

Table 3 The Association Between Race and Other Demographics and with the Odds of Having a Thinnest Pachymetry <400 µm at Presentation

Demographics	Pachymetry <400 µm	Pachymetry ≥400 µm	Odds Ratio (95% CI), p-value, Bivariate, Unadjusted	Odds Ratio (95% CI), p-value, Multivariate, Adjusted
Race, n (%)				
Black	41/69 (59.4)	51/182 (28.0)	3.82 (1.91, 7.65), p<0.0001*	4.40 (2.00, 9.67), p<0.0001*
Non-black	28/69 (40.6)	131/182 (72.0)	Reference group	Reference group
Mean age ± SD (years)	32.0 ± 13.2	35.0 ± 13.1	0.98 (0.96, 1.01), p=0.173	0.98 (0.95, 1.02), p=0.334
Sex, n (%)				
Female	24/69 (34.8)	58/182 (31.9)	1.11 (0.55, 2.25), p=0.773	0.81 (0.35, 1.83), p=0.607
Male	45/69 (65.2)	124/182 (68.1)	Reference group	Reference group
Insurance, n (%)				
None	4/69 (5.8)	12/182 (6.6)	1.23 (0.30, 5.06), p=0.778	0.91 (0.19, 4.28), p=0.908
Public/VA	25/69 (36.2)	25/182 (13.7)	3.68 (1.68, 8.06), p=0.001*	2.51 (1.06, 5.97), p=0.037*
Private	40/69 (58.0)	145/182 (79.7)	Reference group	Reference group
Referral, n (%)				
Self/None	18/69 (26.1)	29/182 (15.9)	2.04 (0.82, 5.06), p=0.124	2.21 (0.74, 6.54), p=0.153
OD	29/69 (42.0)	80/182 (44.0)	1.19 (0.55, 2.56), p=0.656	1.17 (0.50, 2.73), p=0.723
MD	22/69 (31.9)	73/182 (40.1)	Reference group	Reference group
Correction, n (%)				
Contact lenses	35/69 (50.7)	82/182 (45.1)	1.25 (0.64, 2.43), p=0.518	1.57 (0.74, 3.36), p=0.242
Glasses/none	34/69 (49.3)	100/182 (54.9)	Reference group	Reference group
Provider, n (%)				
Other Provider	36/69 (52.2)	71/182 (39.0)	1.65 (0.85, 3.23), p=0.141	1.38 (0.62, 3.10), p=0.434
Provider 1	33/69 (47.8)	111/182 (61.0)	Reference group	Reference group

Notes: Bivariate unadjusted generalized estimating equations (GEE) were between demographic or clinical characteristics (independent variable) and thinnest pachymetry <400 µm (dependent variable). Multivariable adjusted GEE included race, age, sex, insurance type, referring provider, treating cornea specialist, and prior treatment with glasses/contact lenses. *Statistically significant value.

Abbreviations: MD, physician-referred; OD, optometrist-referred; SD, standard deviation; VA, veteran affairs.

Table 4 The Association Between Race and Other Demographics with the Odds of Having Corneal Scarring at Presentation

Demographics	Corneal Scarring	No Corneal Scarring	Odds Ratio (95% CI), p-value, Bivariate, Unadjusted	Odds Ratio (95% CI), p-value, Multivariate, Adjusted
Race, n (%)				
Black	35/59 (59)	57/192 (30)	3.50 (1.74, 7.05), p<0.0001*	3.43 (1.61, 7.31), p=0.001*
Non-black	24/59 (41)	135/192 (70)	Reference group	Reference group
Mean age ± SD, years	35.1 ± 12.2	33.9 ± 13.5	1.01 (0.98, 1.03), p=0.634	1.01 (0.98, 1.04), p=0.426
Sex, n (%)				
Female	18/59 (31)	64/192 (33)	0.86 (0.41, 1.79), p=0.690	0.59 (0.26, 1.35), p=0.214
Male	41/59 (69)	128/192 (67)	Reference group	Reference group
Insurance, n (%)				
None	3/59 (5)	13/192 (7)	0.93 (0.21, 4.17), p=0.928	0.86 (0.17, 4.43), p=0.857
Public/VA	19/59 (32)	31/192 (16)	2.48 (1.14, 5.37), p=0.022*	2.55 (1.06, 6.14), p=0.037*
Private	37/59 (63)	148/192 (77)	Reference group	Reference group
Referral, n (%)				
Self/none	11/59 (19)	36/192 (19)	0.69 (0.27, 1.77), p=0.443	0.91 (0.32, 2.60), p=0.854
OD	19/59 (32)	90/192 (47)	0.48 (0.22, 1.03), p=0.060	0.43 (0.19, 0.98), p=0.045*
MD	29/59 (49)	66/192 (34)	Reference group	Reference group
Correction, n (%)				
Contact lenses	26/59 (44)	91/192 (47)	0.87 (0.44, 1.72), p=0.691	0.95 (0.45, 1.99), p=0.896
Glasses/none	33/59 (56)	101/192 (53)	Reference group	Reference group
Provider, n (%)				
Other provider	24/59 (41)	83/192 (43)	0.88 (0.44, 1.76), p=0.720	0.78 (0.35, 1.75), p=0.544
Provider 1	35/59 (59)	109/192 (57)	Reference group	Reference group

Notes: Bivariate unadjusted generalized estimating equations (GEE) were between demographic or clinical characteristics (independent variable) and corneal scarring (dependent variable). Multivariable adjusted GEE included race, age, sex, insurance type, referring provider, treating cornea specialist, and prior treatment with glasses/contact lenses. *Statistically significant value.

Abbreviations: MD, physician-referred; OD, optometrist-referred; SD, standard deviation; VA, veteran affairs.

Table 5 The Association Between Race and Other Demographics with the Odds of Having Keratoplasty[a] Recommended at Presentation

Demographics	Keratoplasty	Other Treatment	Odds Ratio (95% CI), p-value, Bivariate, Unadjusted	Odds Ratio (95% CI), p-value, Multivariate, Adjusted
Race, n (%)				
Non-black	3/159 (1.9)	156/159 (98.1)	6.33 (1.76, 22.73), p=0.005*	7.75 (1.89, 31.75), p=0.004*
Black	10/92 (10.9)	82/92 (89.1)	Reference group	Reference group
Mean Age ± SD, years	36.1 ± 9.8	34.1 ± 13.4	1.01 (0.97, 1.06), p=0.590	1.01 (0.96, 1.06), p=0.686
Sex, n (%)				
Female	4/13 (31)	78/238 (33)	0.91 (0.28, 2.96), p=0.881	0.57 (0.15, 2.13), p=0.404
Male	9/13 (69)	160/238 (67)	Reference group	Reference group
Insurance, n (%)				
None	0/13 (0)	16/238 (7)	–	–
Public/VA	4/13 (31)	46/238 (19)	1.70 (0.52, 5.55), p=0.381	1.91 (0.48, 7.57), p=0.358
Private	9/13 (69)	176/238 (74)	Reference group	Reference group

(*Continued*)

Table 5 (Continued).

Demographics	Keratoplasty	Other Treatment	Odds Ratio (95% CI), p-value, Bivariate, Unadjusted	Odds Ratio (95% CI), p-value, Multivariate, Adjusted
Referral, n (%)				
Self/none	2/13 (15)	45/238 (19)	0.48 (0.10, 2.27), p = 0.357	1.18 (0.20, 7.0), p = 0.856
OD	3/13 (23)	106/238 (45)	0.31 (0.08, 1.15), p=0.080	0.23 (0.06, 0.98), p=0.046*
MD	8/13 (62)	87/238 (37)	Reference group	Reference group
Correction, n (%)				
Contact Lenses	6/13 (46)	111/238 (47)	0.98 (0.33, 2.91), p=0.970	1.41 (0.42, 4.76), p=0.575
Glasses/none	7/13 (54)	127/238 (53)	Reference group	Reference group
Provider, n (%)				
Other provider	3/13 (27)	104/238 (44)	0.39 (0.11, 1.40), p=0.146	0.28 (0.06, 1.31), p=0.106
Provider 1	10/13 (73)	134/238 (56)	Reference group	Reference group

Notes: Bivariate unadjusted generalized estimating equations (GEE) were between demographic or clinical characteristics (independent variable) and corneal scarring (dependent variable). Multivariable adjusted GEE included race, age, sex, insurance type, referring provider, treating cornea specialist, and prior treatment with glasses/contact lenses. *Statistically significant value. [a]Keratoplasty includes deep anterior lamellar keratoplasty (DALK) and penetrating keratoplasty (PKP).
Abbreviations: MD, physician-referred; OD, optometrist-referred; SD, standard deviation; VA, veteran affairs.

Thinnest pachymetry <400 µm was significantly associated with the presence of corneal scarring (OR 23.8, 95% CI [11.0, 51.4]; p < 0.0001), worse logMAR CDVA score (beta coefficient 0.41, 95% CI [0.30, 0.53]; p < 0.0001), and a higher likelihood of being recommended keratoplasty (OR 9.95, 95% CI [2.80, 36.6]; p = 0.001). When the multivariable model of corneal scarring at presentation was adjusted for thinnest pachymetry <400 µm, black race was no longer significantly associated with higher odds of corneal scarring (p = 0.469). Similarly, the association between black race and recommended treatment with keratoplasty was attenuated when adjusted for pachymetry <400 µm (OR 3.65, p = 0.082). However, if the multivariable model for logMAR CDVA score was adjusted for pachymetry <400 µm, the association with black race was mildly attenuated but still significantly associated with a worse logMAR CDVA score (p = 0.001). This suggests that the association between black race and these outcomes is related to more advanced corneal thinning in black eyes at presentation. When the interaction between black race and pachymetry <400 µm was tested in each of these three models, there was no effect modification by the thinnest pachymetry (all p > 0.05).

Discussion

This study demonstrated that black eyes presented with more advanced signs of KCN than non-black eyes, including a worse (higher) ABCD score, a thinnest pachymetry <400 µm, and corneal scarring. They also had worse visual acuity and a higher likelihood of being recommended for more invasive management with keratoplasty than CXL, CL, or other. These findings were independent of multiple potential confounders, most notably insurance status and referral source. To the best of our knowledge, this is the first study to demonstrate that blacks with KCN are more likely to require more invasive surgical management, such as keratoplasty.

Racial differences in corneal morphology may contribute to the risk of progression to advanced KCN. Blacks have been shown to have thinner central corneal thickness which progresses over time.[22] Such thinner corneas are an independent risk factor for the development of glaucoma,[23] and the higher prevalence of thin corneas among blacks may contribute to the higher rates of glaucomatous progression observed in black communities.[24,25] Another recent study has also reported an association between black race and higher Kmax, thinner central corneas, and worse visual acuity compared to whites with KCN.[26] Similarly, our study's results suggest that thinner corneas may place black individuals at a higher predisposition for progression to more severe ectatic disease due to KCN. Of note, we also explored the effect of controlling for the thinnest pachymetry measurement <400 µm in final multivariable models and observed that black race was no longer associated with higher odds of corneal scarring or higher odds of keratoplasty recommendation. However, there was still a significant association between black race and worse logMAR CDVA score. Thus, very thin corneas may explain the relationship

between black race and complications from KCN such as corneal scarring and the need for more invasive surgery but may not fully explain why blacks had worse visual acuity.

While surgical procedures such as DALK and PKP can be effective in the management of KCN, they entail more risks than treatment with CXL or scleral CL, including risk of infection and graft rejection. Additionally, many patients who receive a corneal transplant will require a revisional operation within 10–20 years.[27] Thus, transplant is often only a temporary solution for KCN patients, who are relatively young at diagnosis (average 34.2 ± 13.2 years in this study; average 28.3 years in a large population study in the Netherlands).[28] Consequently, early detection of KCN and subsequent treatment with CXL is even more vital because it can allow patients to avoid multiple corneal transplants and their associated risks. It is possible that black individuals may benefit from screening for KCN at a younger age, particularly if there is a family history of KCN or a known history of eye rubbing, which is a known risk factor for KCN,[29] perhaps due to atopic disease.

Differences in sex distribution between black and non-black populations may highlight other potential inequities. Some studies have suggested that KCN is a male-predominant disease.[28,30] However, in this study, black men were less likely to present with KCN than non-black men. This could be explained by the theory that black men have less trust in the medical system than other populations, such as black women or white men,[31] making them less likely to present for an evaluation. Of note, a recent large meta-analysis did not find a significant difference in the prevalence of KCN by male or female sex.[2] Future studies could examine whether black males are less likely to be evaluated for KCN than non-black males or if there are biological sex-based differences in KCN prevalence.

Although there are also documented disparities in health insurance rates among black patients in the United States,[32] blacks had more advanced KCN, independent of insurance status. However, public or VA insurance was an independent risk factor for advanced KCN. These patients had higher odds of a thinnest pachymetry <400 μm, higher odds of corneal scarring, and a worse average logMAR CDVA score than those with private health insurance. Future studies could evaluate whether this difference is due to the quality of care received with public insurance or other confounding variables present within the population that qualifies for US public healthcare insurance.

Another observation was that patients referred by an optometrist were less likely to have corneal scarring and had lower (better) logMAR CDVA scores at presentation. It is possible that patients referred by optometry had more regular examinations for refractive correction, enabling earlier detection of corneal thinning and ectasia on slit-lamp exam. In contrast, patients referred for corneal evaluation by other physicians had more advanced disease. It is possible that other ophthalmologists acted as intermediaries between referrals by optometry or self-referral and referral to cornea specialists, resulting in delayed presentation to this center's cornea department. Additionally, primary care physicians do not regularly perform adequate ophthalmic examinations and, consequently, may be less likely to refer patients until they report substantial visual symptoms or have notable opacification due to corneal scarring.

This study has several limitations. Due to its retrospective nature, the study was limited to the data available in the electronic health record, and some of the associations may be related to unmeasured confounding factors or other risk factors. Future studies should investigate whether access to healthcare,[8] historical distrust in the healthcare system,[33] bias in referral patterns,[34] differences in SES,[7] and genetic variability[35] are associated with delayed presentation for KCN evaluation. Such projects could also evaluate whether differences in known risk factors for KCN among black and non-black patients, such as eye rubbing, positive family history, allergies, and asthma,[2,3] are related to differences in the stage of their disease at presentation. Additionally, this study was not powered to examine differences in the presentation of KCN among other minority racial or ethnic groups, but this could be done in larger studies or in other settings with greater access to those patient populations. Another limitation of this study was the manner in which KCN staging was determined and how this affected the initial treatment recommendations. Since CXL is only beneficial to patients with progressive KCN disease,[21] before recommending a patient for CXL, the cornea specialist must determine whether a patient's KCN is likely to progress or if it has halted in its current state. At times, this requires a follow-up visit with additional keratometry measurements. Consequently, some patients received CXL recommendations after it was determined that their disease had progressed during a later evaluation while the initial recommendation may have been to follow-up in 3 months. Similarly, some patients with advanced, yet non-progressive, KCN were recommended CL before resorting to DALK or PKP.

Conclusion

In conclusion, black patients presented with multiple signs and symptoms of more advanced KCN than non-blacks, and on initial evaluation, they were more likely to be recommended for more invasive surgical management with keratoplasty rather than less invasive medical management (ie, glasses, CL) or CXL. We suggest that the late presentation of disease may have precluded the benefits of CXL. The reasons for such disparities are multifactorial and likely include genetic, anatomical, and sociological factors. Future studies should consider whether screening for KCN in young adult black populations could increase the likelihood of less invasive management recommendations, such as CXL, and ultimately improve anatomical and visual outcomes.

Acknowledgments

Matthew Giegengack and Atalie C Thompson are co-senior authors. Keith Walter, Dr Michelle Patel, Dr Ramunas Rolius, Dr Krishna Surapaneni, Dr Ryan Chenevey, Dr Nathan Anderson, and Dr Han Yin for caring for these patients.

Disclosure

Dr Atalie Thompson reports personal fees from Topcon Medical, grants from NIH, and grants from Doris Duke Foundation, outside the submitted work. The other authors have no conflicts of interest for this work.

References

1. Gokhale NS. Epidemiology of keratoconus. *Indian J Ophthalmol*. 2013;61(8):382–383. doi:10.4103/0301-4738.116054
2. Hashemi H, Heydarian S, Hooshmand E, et al. The prevalence and risk factors for keratoconus: a systematic review and meta-analysis. *Cornea*. 2020;39(2):263–270. doi:10.1097/ICO.0000000000002150
3. Feldman BH, Kozak A, Sheth S, et al. Keratoconus. EyeWiki. Available from: https://eyewiki.aao.org/Keratoconus. Accessed January 4, 2024.
4. Arnalich-Montiel F, Alió Del Barrio JL, Alió JL. Corneal surgery in keratoconus: which type, which technique, which outcomes? *Eye Vis*. 2016;3:2. doi:10.1186/s40662-016-0033-y
5. Randleman JB, Khandelwal SS, Hafezi F. Corneal cross-linking. *Surv Ophthalmol*. 2015;60(6):509–523. doi:10.1016/j.survophthal.2015.04.002
6. Galvis V, Tello A, Ortiz AI, et al. Patient selection for corneal collagen cross-linking: an updated review. *Clin Ophthalmol*. 2017;11:657–668. doi:10.2147/OPTH.S101386
7. Ahmad TR, Kong AW, Turner ML, et al. Socioeconomic Correlates of Keratoconus Severity and Progression. *Cornea*. 2023;42(1):60–65. doi:10.1097/ICO.0000000000002993
8. Szczepura A. Access to health care for ethnic minority populations. *Postgrad Med J*. 2005;81(953):141–147. doi:10.1136/pgmj.2004.026237
9. Groman R, Ginsburg J. American College of Physicians. Racial and ethnic disparities in health care: a position paper of the American College of Physicians. *Ann Intern Med*. 2004;141(3):226–232.
10. Benjamins MR, Silva A, Saiyed NS, et al. Comparison of all-cause mortality rates and inequities between black and white populations across the 30 most populous US cities. *JAMA Network Open*. 2021;4(1):e2032086. doi:10.1001/jamanetworkopen.2020.32086
11. Heckenlaible NJ, Dun C, Prescott C, et al. Predictors of receiving keratoplasty for fuchs' endothelial corneal dystrophy among medicare beneficiaries. *Ophthalmology*. 2023;130(1):28–38. doi:10.1016/j.ophtha.2022.07.030
12. Mahr MA, Hodge DO, Erie JC. Racial/ethnic differences in rates of complex cataract surgery among United States Medicare beneficiaries. *J Cataract Refract Surg*. 2018;44(2):140–143. doi:10.1016/j.jcrs.2017.10.049
13. Qiu M, Wang SY, Singh K, et al. Racial disparities in uncorrected and undercorrected refractive error in the United States. *Invest Ophthalmol Vis Sci*. 2014;55(10):6996–7005. doi:10.1167/iovs.13-12662
14. Stein JD, Talwar N, LaVerne AM, et al. Racial disparities in the use of ancillary testing to evaluate individuals with open-angle Glaucoma. *Arch Ophthalmol*. 2012;130(12):1579–1588. doi:10.1001/archophthalmol.2012.1325
15. Barsegian A, Kotlyar B, Lee J, et al. Diabetic retinopathy: focus on minority populations. *Int J Clin Endocrinol Metab*. 2017;3(1):034–45. doi:10.17352/ijcem.000027
16. Phillips PH, Newman NJ, Lynn MJ. Optic Neuritis in African Americans. *Arch Neurol*. 1998;55(2):186–192. doi:10.1001/archneur.55.2.186
17. Halawa OA, Jin Q, Pasquale LR, et al. Race and ethnicity differences in disease severity and visual field progression among glaucoma patients. *Am J Ophthalmol*. 2022;242:69–76. doi:10.1016/j.ajo.2022.05.023
18. Thompson AC, Vu DM, Cowan LA, et al. Factors associated with interventions after laser peripheral iridotomy for primary angle-closure spectrum diagnoses. *Ophthalmol Glaucoma*. 2019;2(3):192–200. doi:10.1016/j.ogla.2019.03.003
19. Belin MW, Kundu G, Shetty N, et al. ABCD: a new classification for keratoconus. *Indian J Ophthalmol*. 2020;68(12):2831–2834. doi:10.4103/ijo.IJO_2078_20
20. Deshmukh R, Hafezi F, Kymionis GD, et al. Current concepts in crosslinking thin corneas. *Indian J Ophthalmol*. 2019;67(1):8–15. doi:10.4103/ijo.IJO_1403_18
21. Feldman BH, Bernfeld E, Reddy V, et al. Corneal Collagen Cross-Linking. EyeWiki. Available from: https://eyewiki.aao.org/Corneal_Collagen_Cross-Linking. Accessed April 10, 2023.
22. Mwanza JC, Tulenko SE, Budenz DL, et al. Longitudinal change in central corneal thickness in the tema eye survey. *Am J Ophthalmol*. 2018;186:10–18. doi:10.1016/j.ajo.2017.11.002

23. Gordon MO, Beiser JA, Brandt JD, et al. The ocular hypertension treatment study: baseline factors that predict the onset of primary open-angle glaucoma. *Arch Ophthalmol*. 2002;120(6):714–830. doi:10.1001/archopht.120.6.714
24. Brandt JD, Beiser JA, Kass MA, et al. Central corneal thickness in the ocular hypertension treatment study (OHTS). *Ophthalmology*. 2001;108 (10):1779–1788. doi:10.1016/S0161-6420(01)00760-6
25. Haseltine SJ, Pae J, Ehrlich JR, et al. Variation in corneal hysteresis and central corneal thickness among black, Hispanic and white subjects. *Acta Ophthalmol*. 2012;90(8):e626–e631. doi:10.1111/j.1755-3768.2012.02509.x
26. Nugent L, Son HS, Wang J, et al. Racial variation in visual impairment of patients with keratoconus at presentation. *Cornea*. 2023. doi:10.1097/ICO.0000000000003302
27. Borderie VM, Boëlle PY, Touzeau O, et al. Predicted long-term outcome of corneal transplantation. *Ophthalmology*. 2009;116(12):2354–2360. doi:10.1016/j.ophtha.2009.05.009
28. Godefrooij DA, de Wit GA, Uiterwaal CS, et al. Age-specific incidence and prevalence of keratoconus: a nationwide registration study. *Am J Ophthalmol*. 2017;175:169–172. doi:10.1016/j.ajo.2016.12.015
29. Sugar J, Macsai MS. What causes keratoconus? *Cornea*. 2012;31(6):716–719. doi:10.1097/ICO.0b013e31823f8c72
30. Yang K, Gu Y, Xu L, et al. Distribution of pediatric keratoconus by different age and gender groups. *Front Pediatr*. 2022;10:937246. doi:10.3389/fped.2022.937246
31. Idan E, Xing A, Ivory J, et al. Sociodemographic Correlates of Medical Mistrust among African American Men Living in the East Bay. *J Health Care Poor Underserved*. 2020;31(1):115–127. doi:10.1353/hpu.2020.0012
32. Sohn H. Racial and ethnic disparities in health insurance coverage: dynamics of gaining and losing coverage over the life-course. *Popul Res Policy Rev*. 2017;36(2):181–201. doi:10.1007/s11113-016-9416-y
33. Boulware LE, Cooper LA, Ratner LE, et al. Race and trust in the health care system. *Public Health Rep*. 2003;118(4):358–365. doi:10.1016/S0033-3549(04)50262-5
34. Chapman EN, Kaatz A, Carnes M. Physicians and implicit bias: how doctors may unwittingly perpetuate health care disparities. *J Gen Intern Med*. 2013;28(11):1504–1510. doi:10.1007/s11606-013-2441-1
35. Mayo Clinic. Mayo foundation for medical education and research. Keratoconus. Available from: https://www.mayoclinic.org/diseases-conditions/keratoconus/diagnosis-treatment/drc-20351357. Accessed April 10, 2023.