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Cataract & Refractive Surgery Today

KERATOCONUS TESTING CONSENSUS STATEMENT:

Understanding the
Incidence and Impact of
Keratoconus in Corneal
Refractive Surgery &
Reviewing New Standards
to Preemptively Identify
These Patients

A CME/CE activity jointly provided by
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KERATOCONUS TESTING CONSENSUS STATEMENT: UNDERSTANDING THE INCIDENCE AND IMPACT OF KERATOCONUS IN CORNEAL REFRACTIVE SURGERY & REVIEWING NEW STANDARDS TO PREEMPTIVELY IDENTIFY THESE PATIENTS

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CONTENT SOURCE

This continuing medical education (CME/CE) activity captures content from two roundtable discussions.

ACTIVITY DESCRIPTION

World class leaders assembled to discuss and vote on best practices and guidelines for understanding the incidence and impact of keratoconus in corneal refractive surgery and reviewing new standards to preemptively identify these patients. Topics of discussion included defining the fundamental etiology and progression of keratoconus, identifying the prevalence and demographics of keratoconus in various patient populations, diagnosing keratoconus and the importance of early detection using genetic testing, as well as the impact of keratoconus on patient and refractive surgery practices. The results of that discussion are summarized in this supplement.

TARGET AUDIENCE

This certified CE/CME activity is designed for ophthalmologists and optometrists.

LEARNING OBJECTIVES

Upon completion of this activity, the participant should be able to:

- **Define** etiology and progression of keratoconus, understand how refractive surgery can exacerbate these conditions, and review the impact this has on visual outcomes and quality of life
- **Describe** the prevalence of the refractive surgery patients developing keratoconus in various patient populations
- **Identify** the accuracy of various conventional and new genetic testing metrics for identifying refractive surgery patients who may be at risk for developing keratoconus
- **Recommend** diagnostic work-up protocols and pre-emptive testing indications for various groups of refractive surgery patients to maximize the diagnosis of keratoconus suspects
- **Review** treatment options for refractive surgery candidates who have or are likely to develop keratoconus

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PRETEST QUESTIONS

PLEASE COMPLETE PRIOR TO ACCESSING THE MATERIAL AND SUBMIT WITH POSTTEST/ACTIVITY EVALUATION/SATISFACTION MEASURES FOR CE/CME CREDIT.

1. Please rate your confidence in your ability to understand how refractive surgery can exacerbate the progression of keratoconus (based on a scale of 1 to 5, with 1 being not at all confident and 5 being extremely confident).

- A. 1
- B. 2
- C. 3
- D. 4
- E. 5

2. Which of the following were/was reported to be mandatory finding/s to diagnose keratoconus according to the 2015 Global Consensus on Keratoconus and Ectatic Disease?

- A. Clinically inflammatory corneal thickening
- B. Abnormal posterior ectasia
- C. Abnormal corneal thickness distribution
- D. B & C

3. When discussing keratoconus, clinicians probably would NOT ask the patient about _____.

- A. Eye rubbing
- B. Usual sleeping position
- C. Family history
- D. Lid hygiene

4. _____ was reported to be a risk factor for keratoconus.

- A. Elevated intraocular pressure
- B. Diabetic retinopathy
- C. Allergy
- D. Hyperthyroidism

5. Which technology/ies provide/s information on the posterior corneal curvature?

- A. Pachymetry
- B. Corneal tomography
- C. Corneal topography
- D. A & C

6. Panelists use the following top two criteria for evaluating keratoconus most frequently: _____.

- A. Abnormal posterior curvature and abnormal corneal thickness
- B. Clinically inflammatory corneal thinning and abnormal posterior distribution
- C. Abnormal topography and abnormal corneal thickness and distribution
- D. None of the above

7. _____ can accelerate the progression of keratoconus.

- A. Hypertrophic cardiomyopathy
- B. Pregnancy
- C. Menopause
- D. A & C

8. On corneal tomography, _____ is considered a red flag for keratoconus.

- A. Posterior elevation greater than 15 to 20 µm
- B. Thinnest pachymetry less than 600 µm
- C. Anterior elevation greater than 7 µm
- D. B & C

9. In practices without advanced diagnostic technology, _____ can be a red flag for keratoconus in a young patient.

- A. Progressive hyperopia
- B. Inability to correct to VA 20/20
- C. Dysphotopsia
- D. None of the above

10. _____ helps assess a patient's future risk of keratoconus based on an underlying risk factor for the disease.

- A. Genetic testing for keratoconus
- B. Corneal topography
- C. Wavefront aberrometry
- D. Autorefraction

11. The 2020 Market Scope keratoconus analysis reported that _____ people worldwide have keratoconus.

- A. 13 million
- B. 33 million
- C. 43 million
- D. 63 million

12. Which finding would prompt panelists to order genetic testing to determine the risk of keratoconus?

- A. Neovascularization
- B. Family history of keratoconus
- C. Progressive hyperopia
- D. Keratometry values greater than 37.00 D

13. Which of the following may slow or stop progression of keratoconus?

- A. Corneal crosslinking
- B. Hybrid contact lenses
- C. Scleral contact lenses
- D. None of the above

14. The following is true about genetic testing for keratoconus: _____.

- A. It does not require a large capital outlay
- B. It indicates the progression rate of keratoconus
- C. It tests 55 genes
- D. It indicates the severity of keratoconus

15. All panelists believe _____ is the most accurate diagnostic tool to detect keratoconus prior to loss of visual function.

- A. Corneal biomechanics tests
- B. Optical coherence tomography
- C. Corneal topography
- D. Corneal tomography

16. All panelists recommended _____ for ALL corneal refractive surgery candidates to help identify keratoconus suspects.

- A. Corneal tomography
- B. Corneal topography
- C. Pachymetry
- D. Wavefront aberrometry

KERATOCONUS TESTING CONSENSUS STATEMENT: Understanding the Incidence and Impact of Keratoconus in Corneal Refractive Surgery & Reviewing New Standards to Preemptively Identify These Patients

FUNDAMENTAL ETIOLOGY AND DEFINITION OF KERATOCONUS

Keratoconus, a progressive corneal condition, significantly affects the vision of young patients and their quality of life (Figure). “Many of these patients go on to corneal transplantation,” said Eric D. Donnenfeld, MD.

However, new diagnostic and treatment technologies offer hope for these patients.

“With the advent of highly sensitive technologies that enable eyecare professionals to detect the disease far earlier in its continuum, along with the development of treatments that can halt progression, a true paradigm shift in keratoconus management has taken place,” said S. Barry Eiden, OD, FAAO.

DEFINING KERATOCONUS

According to the 2015 Global Consensus on Keratoconus and Ectatic Disease, mandatory findings to diagnose keratoconus are abnormal posterior ectasia, abnormal corneal thickness distribution, and clinically noninflammatory corneal thinning.¹

“There are multiple factors that affect keratoconus and its clinical manifestation,” said Elizabeth Yeu, MD. “Some factors may be inherent with different genetic components that are linked more positively and then there are other environmental factors.” For example, allergies may cause patients to rub their eyes vigorously.

Mile Brujic, OD, FAAO, explained that patients with a lower genetic risk but higher environmental risk factors may develop the condition versus those who have slightly increased genetic risks in the absence of some of the environmental risk factors.

Diagnostic methods have changed through the years, according to Richard L. Lindstrom, MD.

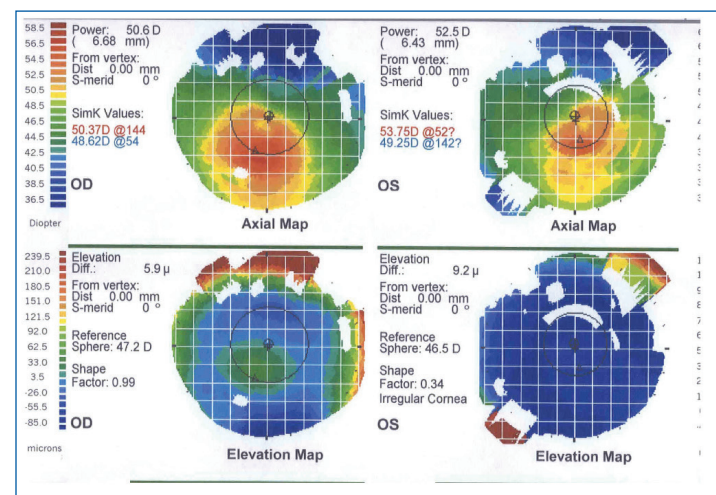


Figure. A 26-year-old athlete with progressive keratoconus and anisometropia.

Today it is a topography/tomography diagnosis,” he said. “Early on, we look for steepness of the cornea anteriorly; typically, greater than 48.00 D is abnormal. We look for an asymmetric bowtie pattern with skew deviation, where the bowtie pattern of astigmatism doesn’t align. It’s tilted.”

Dr. Lindstrom explained that posterior elevation is especially important as an early sign. “That’s where it often shows up first, with steepening of the posterior curvature of the cornea,” he said. “On topography, the cornea is usually thinner in that area of steepening, so we look at the pachymetry and the distribution of the pachymetry. An epithelial map will also show compensatory epithelial thinning over the cone.”

“Although Placido topography, unlike tomography, only provides information on the front surface of the cornea, it’s still a valuable tool in the detection of early keratoconus,” said Gloria Chiu, OD, FAAO. She considers the following red flags for keratoconus:

asymmetry within the cornea, average K values of 47.00 D or greater, and asymmetry in K values among the patient’s eyes.

Andrew S. Morgenstern, OD, FAAO, explained that the Scheimpflug camera extrapolates the elevation of the front and back surface of the cornea. Assessment of the posterior curvature is important because the cornea steepens and thins with time in keratoconus.

“As we watch the cornea dynamically change with time with keratoconus, the posterior side of the cornea elevates and moves forward at a faster rate than the front surface,” Dr. Morgenstern said, adding that the first change is advancement of the posterior surface toward the anterior surface. “Measuring that elevation change and difference over time is critical to the positive, true diagnosis of the disease.”

However, some clinicians do not have access to corneal tomography or topography. Neda Shamie, MD, explained that there is cause for suspicion in patients younger than 40 with a progressive myopic shift onset in their teens, particularly with an increase in astigmatism; asymmetric change in one eye more than the other; and a decrease in best spectacle-corrected visual acuity. Add to this a family history and/or history of eye rubbing due to allergies, and suspicion is further increased.

“These signs and symptoms captured on simple history and a basic clinical examination can be enough to encourage the doctor who does not have access to advanced diagnostics to refer to a cornea specialist who can make that diagnosis,” Dr. Shamie said.

Dr. Donnenfeld explained that he has often seen patients whose chief complaint was that their vision could not be refracted to 20/20 who were then diagnosed with keratoconus. “Therefore, the earlier these patients are referred, the better their prognosis,” he said. “Many of our colleagues also do retinoscopy and look for a scissoring reflex. That can be very helpful in making the diagnosis as well.”

ADDITIONAL CONSIDERATIONS

Although corneal thickness is important, multiple specific factors must be weighed. John D. Gelles, OD, explained that clinicians cannot rely on ultrasonic pachymetry and stressed the importance of global pachymetry from tomography. “It’s necessary to have a map of corneal thickness to find the thinnest point, but a clinician cannot rely solely on this measurement. The rate of change in corneal thickness from the thinnest point to the periphery (ie, thickness distribution) must be considered,” he said.

“You can have patients with keratoconus who have corneal thickness greater than 550 μ m when you first diagnose them,” said William B. Trattler, MD.²

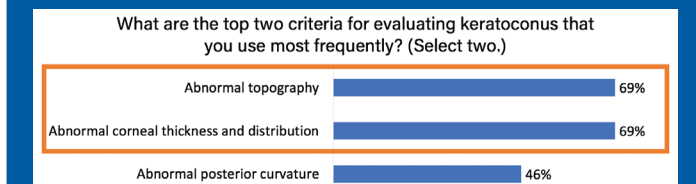


“The earlier these patients are referred, the better their prognosis.”

— Eric D. Donnenfeld, MD

CONSENSUS FINDING #1:

The top two criteria for evaluating keratoconus are abnormal topography and abnormal corneal thickness and distribution.



Dr. Donnenfeld agreed, with a caveat. “Patients with keratoconus certainly can have corneal thicknesses greater than 550 μ m, but they usually have abnormal distributions, so I think they go hand in hand,” he said. “I’ve never seen keratoconus in a thick cornea where the pachymetry is normally distributed.”

According to **Consensus Finding #1**, faculty reported abnormal topography (69%) and abnormal corneal thickness and distribution (69%) are the top two criteria for evaluating keratoconus that they use most frequently. However, they believe all of these metrics are valuable to diagnosis.

“I absolutely agree that abnormal topography is a critical diagnostic in this. It also makes sense that there is equal focus on findings of abnormal posterior corneal curvature and corneal thickness distribution, as these offer further evidence of ectasia,” Dr. Shamie said. “In early keratoconus patients or in those suspected to have keratoconus, steepening of the posterior corneal curvature often precedes that seen on other diagnostics. The same is true for abnormal corneal thickness and epithelial map distribution.”

RISK FACTORS

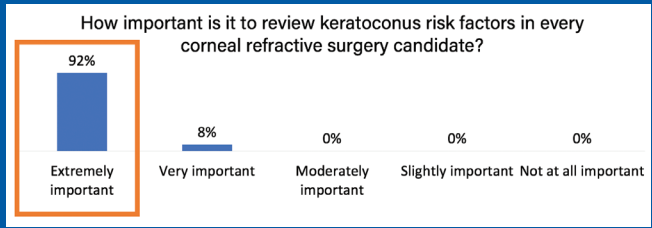
In addition to genetic and environmental risk factors, there are other considerations.

“Younger patients are at higher risk for ectatic disorders because we know that their corneas are not fully crosslinked, and with increasing age, you get a progressively stiffer cornea,” said Terry Kim, MD, adding that he incorporates age as an additional risk factor for ectasia when evaluating a patient for any kind of corneal refractive procedure.

Patients should be asked about a family history of keratoconus. In addition, systemic comorbidities such as Down syndrome, connective tissue disorders such as Marfan syndrome

CONSENSUS FINDING #2:

Twelve of 13 believe that it is extremely important to review keratoconus risk factors in every corneal refractive surgery candidate.



and Ehlers-Danlos syndrome increase the risk, as well as conditions like sleep apnea and mitral valve prolapse.

Patients of certain ethnicities also have been considered to have a higher risk, although some panelists believe more research is needed.

“I think keratoconus is increasing in incidence and prevalence, a lot of it having to do with obesity, eye rubbing, sleep apnea, floppy eyelid syndrome—all of which point toward obesity playing a significant role,” Dr. Donnenfeld said. He noted that at least half of his patients with keratoconus and ectasia after LASIK also have floppy eyelid syndrome.³ Therefore, he looks for that in every patient with keratoconus.

Melissa Barnett, OD, FAAO, FSLs, FBCLA, recommended evaluating all patients with keratoconus for floppy eyelid syndrome and asking about sleep apnea. Validated questionnaires and collaborative care with other specialists can aid with diagnosis and management of these conditions, she said.

Ashley Brissette, MD, explained that the role of genetic factors is not completely understood and will be an important piece of information. “Having access to keratoconus genetic markers may allow us to better predict these genetic risk factors in patients, and if ectasia is a higher risk specifically for them,” she said.

According to **Consensus Finding #2**, 92% of faculty members believe that it is extremely important to review keratoconus risk factors in every corneal refractive surgery candidate.

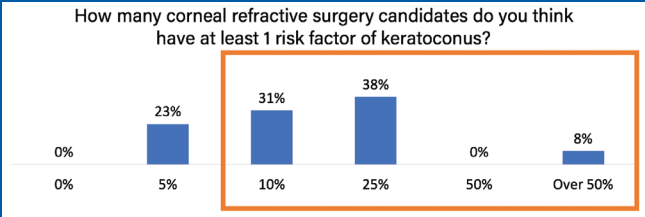
Dr. Barnett agreed that the risk of corneal ectasia needs to be ruled out in every refractive surgery candidate. “Over the years with the assistance of corneal imaging, we have done a better job of evaluating and diagnosing patients for corneal ectasia,” she said. “It is absolutely essential for the best outcomes.”

Dr. Chiu said that she receives many referrals for specialty contact lenses after patients are denied LASIK because of abnormal corneal findings. “I think we are all doing a better job of weeding out poor candidates for refractive surgery,” she said.

According to **Consensus Finding #3**, on average, 20% of corneal refractive surgery candidates have at least one risk factor for keratoconus. Among the faculty members, 10 of 13 believe at least 10% of corneal refractive surgery candidates have at least one risk factor for keratoconus.

CONSENSUS FINDING #3:

- On average, 20% of corneal refractive surgery candidates have at least one risk factor of keratoconus.
- Ten of 13 believe that at least 10% of corneal refractive surgery candidates have at least one risk factor of keratoconus.



Dr. Lindstrom said 10% to 12% of patients seen at larger refractive surgery centers are told that they are not good candidates for refractive surgery. He added that there may be another group of patients in whom surgeons do not feel comfortable performing LASIK and will instead recommend PRK.

Patients having refractive surgery usually are not happy with their vision with glasses, Dr. Donnenfeld said. “Forme fruste keratoconus or early changes in corneal topography may be the reason why,” he explained. “We are selecting patients who are at risk for keratoconus when we offer them refractive surgery.”

PATIENT EDUCATION

Corneal crosslinking has prompted clinicians in Dr. Brujic’s practice to talk to patients sooner about keratoconus.

“It is becoming increasingly important for us to identify this early,” he said. “This is particularly important for those practices that are involved in myopia management and orthokeratology because we do not want to treat someone via orthokeratology who may have early keratoconus,” Dr. Brujic said. “You want to identify those individuals appropriately, manage them appropriately, and start the education process as soon as possible.”

Dr. Barnett always asks patients about vigorous eye rubbing, allergies, and asthma. According to a study by Tretter et al, 80% of patients reported eye rubbing.⁴ “As clinicians, we need to address and manage ocular allergies and atopy because these conditions are associated with keratoconus,” she said.

In addition to discussing eye rubbing and treating allergies that may lead to keratoconus or progression, Dr. Lindstrom asks patients with very asymmetric keratoconus about their sleep position. “There can be environmental trauma from either eye rubbing or sleeping face down on a pillow or on an arm, which can make things worse,” Dr. Lindstrom said.

“In patients who have been chronic eye rubbers, you see changes in the skin around their eyelids, with darkened

pigmentation or leathery changes,” Dr. Shamie said. She also has noticed unexpected eyelid laxity and fine lines around the eyes of young patients, with more significant change on the side with greater ectatic progression.

“If patients are positive for keratoconus and we do genetic testing, they can be educated that they have the potential to have offspring with a more severe form of that disease,” Dr. Morgenstern said. “Now that genetic testing is on the market, it’s part of our responsibility to educate patients.”

CONCLUSIONS

Keratoconus has severe implications, but awareness of and treatments for keratoconus are improving, according to Dr. Yeu. “On the diagnostic side, having better insight can help guide our decisions, and diagnosing earlier can help us treat our patients earlier as well,” she said.

Several factors are believed to increase progression of keratoconus (Figure). Cases occur in younger patients, and eye rubbing, pregnancy, and other factors can accelerate progression.^{1,2}

Ashley Brissette, MD, closely monitors younger patients and those she sees for the first time, asking them to return within a few months for repeat testing.

“If somebody is younger or if they’re rapidly progressing, I think the sooner that you diagnose this condition, the faster you can offer treatment,” Dr. Brissette said. “For example, cross-linking as soon as possible will allow for better visual quality in these patients.”

“The sooner we can diagnose keratoconus, the more manageable it is,” said Mile Brujic, OD, FAAO. This can be accomplished through lifestyle changes and advanced procedures. “We also know that the younger anyone starts with any type of progressive disease, the more advanced it will likely become over a patient’s lifetime,” he added. “Catching it sooner means that we actually potentially delay or forgo the need for ever requiring any type of corneal transplantation.”

According to Melissa Barnett, OD, FAAO, FSLs, FBCLA, patients with keratoconus want to know about the interaction of keratoconus and pregnancy. Findings in the literature have demonstrated that keratoconus progresses in pregnant women and does not regress.¹ “In my female patients of childbearing age, I discuss how the cornea can progress with pregnancy and offer corneal collagen crosslinking sooner rather than later,” Dr. Barnett said.

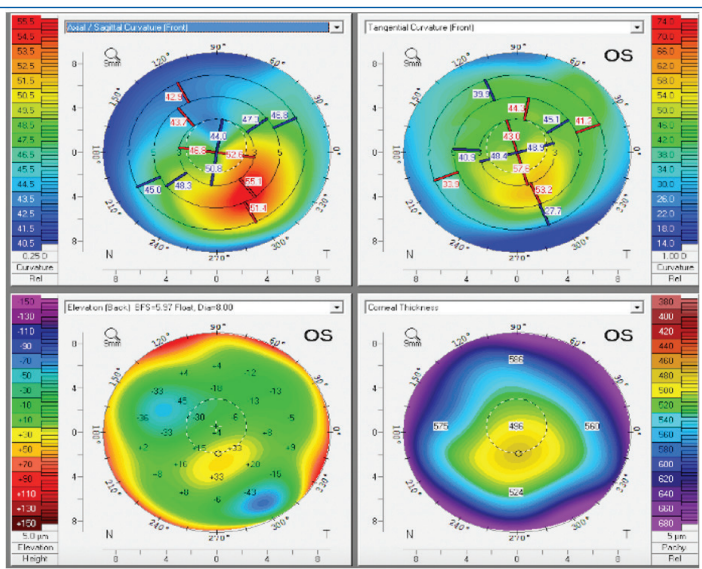


Figure. Scheimpflug imaging demonstrates moderate keratoconus.

ASSESSING PROGRESSION

The key parameters of progression of keratoconus include progressive steepening of the anterior and posterior corneal surfaces and progressive thinning and/or an increase in the rate of corneal thickness change from the periphery to the thinnest point of the cornea.

To gauge progression of keratoconus, William B. Trattler, MD, believes it is most important to monitor the patient’s uncorrected and best corrected visual acuity. “That’s obviously most impactful to patients, as well as ghosting and other symptoms they may complain of,” he said.

Dr. Trattler also stressed the importance of examining the shape of the cornea.

“I look at Kmax,” he said. “But even more importantly, I look at difference maps. These allow you to look at tomography or topography on the initial encounter and then look for changes on the next visit.” If keratoconus is stable, he said, there will be little change from one map to the other, but if it is progressing, the steep part of the cornea is steeper and the flat part is flatter.

Neda Shamie, MD, also looks at corneal thickness maps in areas of thinning. “The progressive thinning of the cornea is obviously part of the pathophysiology and progressive nature of this condition,” she said.

Eric D. Donnenfeld, MD, examines the corneal thickness on corneal tomography. “Keratoconus patients have thinning, and the thinning is usually eccentric,” he said.

“It’s typically more inferior and, as a result, it’s usually correlated with the area of the steepening, which tends to be more progressive,” Dr. Shamie said. “In addition, you can look at epithelial thickness maps. Over the apex of the cone, if you do optical coherence tomography of the epithelium, the epithelial thickness thins over the apex. That could also be a sign of keratoconus.”



“We surely do not want to miss this important diagnosis while thinking that we are dealing with a traditional myopic progression.”

— S. Barry Eiden, OD, FAAO

WORKING WITH AVAILABLE TECHNOLOGY

Some practices may not have advanced diagnostic technology. “A younger adult who does not correct to a sharp 20/20 automatically sets up red flags about a lot of things for me,” said Andrew S. Morgenstern, OD, FAAO. Progressive myopia is also a red flag for keratoconus.

For practices without advanced diagnostics, he recommended the retinoscope and keratometry. “Even though keratoconus is not a central 3-mm disease, because it can happen obviously outside those central 3 mm, looking for distorted mires is critically important as well,” Dr. Morgenstern said.

However, John D. Gelles, OD, emphasized that advanced technologies find subclinical manifestations of the disease far before the visual impact is apparent.

“Structurally, via topography and tomography, they include increased corneal curvature, asymmetry in the anterior corneal curvature, using the inferior-to-superior ratio and axis skew; variations in anterior and, more importantly, posterior corneal elevation; and total and individual layer thickness of the cornea such as abnormal thickness distribution and epithelial thinning,” Dr. Gelles explained. “Objective visual analysis with wavefront aberrometry includes the presence of higher-order aberrations, the most important of which is coma. By combining visual analysis with total corneal analysis, the data points to a corneal origin of the aberrations.” Dr. Gelles also recommended corneal biomechanics and objective risk assessment from genetic testing.

“We surely do not want to miss this important diagnosis while thinking that we are dealing with a traditional myopic progression,” said S. Barry Eiden, OD, FAAO.

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PREVALENCE AND DEMOGRAPHICS OF KERATOCONUS IN VARIOUS PATIENT POPULATIONS

Reports vary regarding the incidence and prevalence of keratoconus (Figures 1 and 2). They also differ by region and diagnostic technologies used in the studies. In 1986, Kennedy et al reported a prevalence of 1 in 2,000 based on a registration study from 1935

to 1982 in Olmstead County, Minnesota.¹ However, a 2017 study of 4.4 million patients in the Netherlands found a prevalence of one in 375.²

The 2020 Market Scope keratoconus analysis reported that 63 million people worldwide have keratoconus; there are 1.6 million preclinical cases in teens and young adults ($K \leq 46.00$ D and ≥ 2.00 D cylinder), and 309 million people have curvatures of at least 46.00 D and less than 48.00 D.

EXAMINING CONTRIBUTING FACTORS

Panelists noted that differences between regions also may reflect ethnic or genetic influences. “The ethnic variations within different populations are variable from place to place,” said Melissa Barnett, OD, FAAO, FSLs, FBCLA.

“There have been studies showing that there’s a higher incidence of keratoconus in patients of Asian descent and of Middle Eastern descent,” said Terry Kim, MD.³⁻⁶

Gloria Chiu, OD, FAAO, believes reported prevalence values in different ethnic and racial groups may be slightly underreported. “I don’t think we can definitively say that there is a higher risk for keratoconus in any particular ethnic or racial group yet,” she said. “I think we still need to look at more comprehensive studies and get better utilization of diagnostic technology to make the correct diagnosis first.”

Dr. Chiu, who practices in a tertiary care hospital in Los Angeles that treats many different ethnic groups, believes she sees keratoconus most often in White and Hispanic patients, followed by Indian-American and Black patients. She sees it least often in patients of East Asian descent. Several panelists practicing in different parts of the country had similar impressions.

Additionally, Neda Shamie, MD, explained that regional variations may also reflect environmental factors. For example, Saudi



Figure 1. A demonstration of advanced keratoconus

Courtesy of Melissa Barnett, OD, FAAO, FSLs, FBCLA

Courtesy of Tom Arnold, OD, FAAO

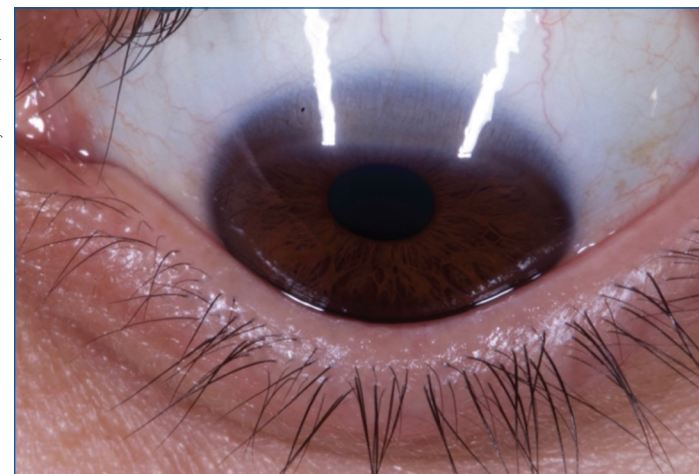


Figure 2. A depiction of Munson's sign, which is a V-shaped indentation of the lower eyelid in down gaze.

Arabia and Iran have a desert climate, which can be associated with allergies.

“We’re seeing more allergy in general in our populations as well,” Dr. Kim said. “If you look at some of these large longitudinal studies, it is amazing how such a high percentage of keratoconus patients have atopic disease. You need to look for patients who have eczema, asthma, or allergic rhinitis. These are all clues that they may have keratoconus as well.”^{7,8}

Patient age also may influence results. Andrew S. Morgenstern, OD, FAAO, explained that the International Keratoconus Academy’s ongoing study on school-age patients has found a high prevalence of keratoconus in these children, although results have not yet been published.

“All eyecare providers—optometrists, ophthalmologists, technicians, and paraprofessionals—need to be on the lookout for keratoconus in this population of patients,” Dr. Morgenstern said. “I was taught keratoconus is the disease of the second to third decade of life. Wrong. We know that patients as young as 5 years old have presented with this disease.”

CONSENSUS FINDING #4:

On average, approximately one in 400 LASIK procedures are performed on keratoconus patients who will develop signs and symptoms during the next 10 years.

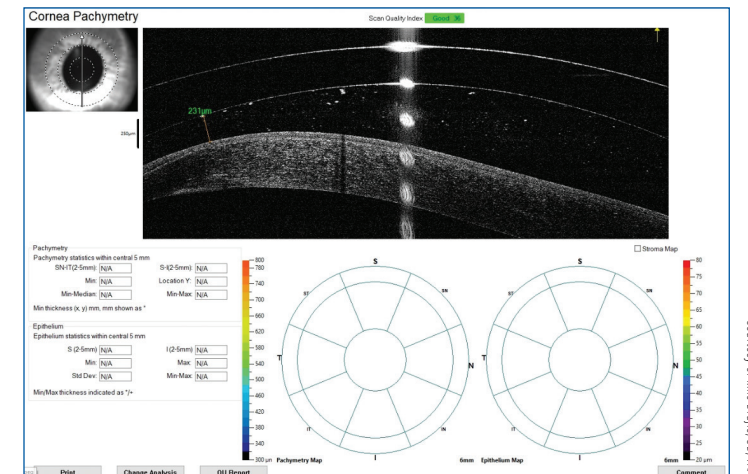


Figure 3. Optical coherence tomography scan of a keratoconic cornea demonstrating corneal irregularity and scleral fit challenges.

Courtesy of Mile Brujic, OD, FAAO

INFLUENCE OF DIAGNOSTICS

Differences in diagnostic technologies between studies may influence discrepancies. Dr. Shamie explained that the study by Kennedy et al was based on detection of scissors reflex with retinoscopy and keratometry outcomes, which often indicate advanced keratoconus.¹ “This is not including forme fruste keratoconus or early keratoconus patients that we would want to be able to detect,” she said.

Increased prevalence in newer studies may also result from earlier detection with improved diagnostics and diagnostic criteria (Figure 3). “As we have pushed diagnostics more into the practices of traditional optometry, we are starting to catch these patients sooner,” said Mile Brujic, OD, FAAO.

“In some of these studies, I think if we reevaluated some of those numbers based on newer diagnostic criteria, we would be surprised,” said Ashley Brissette, MD. She noted that she practices in New York City, with a very diverse population, which likely has a higher proportion of keratoconus patients than the prevalence reported for the general United States.

Despite improvements in diagnosis, panelists stressed that keratoconus consistently needs to be diagnosed earlier.

William B. Trattler, MD, remarked that the majority of referred patients already have moderate to severe keratoconus with vision loss. “There is likely a large number of patients with mild keratoconus in the United States who have not yet been diagnosed,” he said.

RECOGNIZING RISKS IN REFRACTIVE SURGERY CANDIDATES

According to **Consensus Finding #4**, on average, approximately one in 400 LASIK procedures are performed in keratoconus patients who will develop signs and symptoms during the next 10 years.

Richard L. Lindstrom, MD, believes prevalence of post-LASIK ectasia is relatively rare in patients who have no risk factors, but it is not zero.



“There’s no doubt that you can have a completely normal examination and a patient can later develop keratoconus.”

— Richard L. Lindstrom, MD

“There’s no doubt that you can have a completely normal examination and a patient can later develop keratoconus,” Dr. Lindstrom said.

CONCLUSION

“Keratoconus is not that orphan disease of one in 2,000, as once believed,” said Elizabeth Yeu, MD. “The incidence can be extremely common, with a particular predilection with certain ethnicities.”

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DIAGNOSING KERATOCONUS AND THE IMPORTANCE OF EARLY DETECTION USING GENETIC TESTING

The US FDA’s approval of corneal crosslinking to slow or stop progression of keratoconus has dramatically changed treatment of the condition.

“We now have the ability to preserve vision and reduce the number of keratoplasties,” said S. Barry Eiden, OD, FAAO. “As such, early diagnosis has become that much more critical.”

“Diagnosing keratoconus early and recognizing patients at risk for keratoconus has never been more important because, for the first time, we can do something about these patients thanks to treatment with UV crosslinking,” said Eric D. Donnenfeld, MD.

CORNEAL TOPOGRAPHY

Clinicians rely on an array of technologies to diagnose keratoconus.

Mile Brujic, OD, FAAO, performs corneal topography on all contact lens wearers, especially patients undergoing orthokeratology treatment, to monitor the cornea.

Red flags include keratometry values exceeding 47.00 D, axis

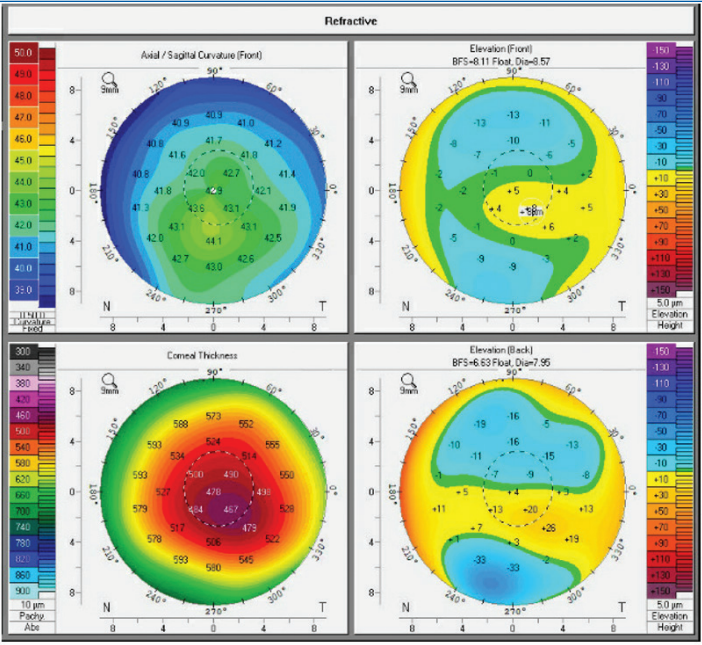


Figure 1. Corneal tomography image OS, less obvious for keratoconus. Corneal thickness map indicates central thinning and posterior elevation map shows abnormal steepening.

skew between the steepest superior and inferior semi-meridians of greater than 20° with greater than 1.50 D of corneal astigmatism, inferior to superior (I-S) keratometry value differences greater than 1.40 D on an axial curvature map, and changes over time.^{1,2}

Corneal topography allows clinicians to monitor patients during a period of time, which is one of the most powerful capabilities, Dr. Brujic said. “I think that’s the leverage that we have with topography,” he said.

“If there is a significant difference of possibly more than 1.50 D of corneal astigmatism, that certainly is going to be more suspicious,” said Elizabeth Yeu, MD. “The difference map is a clear indicator in being able to assess the subtle changes that can occur over time.”

William B. Trattler, MD, explained that the I-S value averages five spots superior to the center and five spots below the center and compares them. “It is a useful criterion, but we have learned that there is important information provided by tomography that can help us identify keratoconus at an earlier time point, as well as identify keratoconus in patients who have a normal I-S value.”

CORNEAL TOMOGRAPHY

Corneal tomography, which assesses the anterior and posterior corneal surfaces, has been a game-changer in early diagnosis of

Courtesy of Gloria Chiu, OD, FAAO

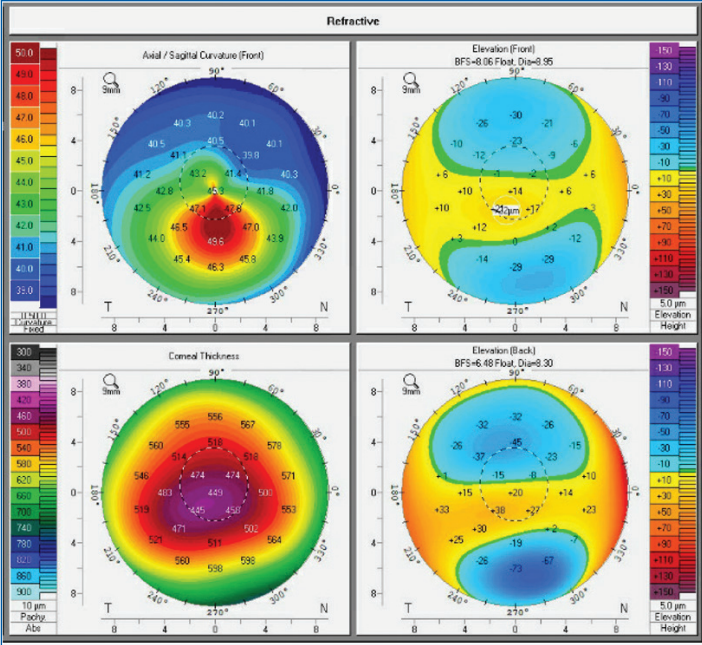


Figure 2. Corneal tomography image OD, with distinct inferior ectasia on the front surface.

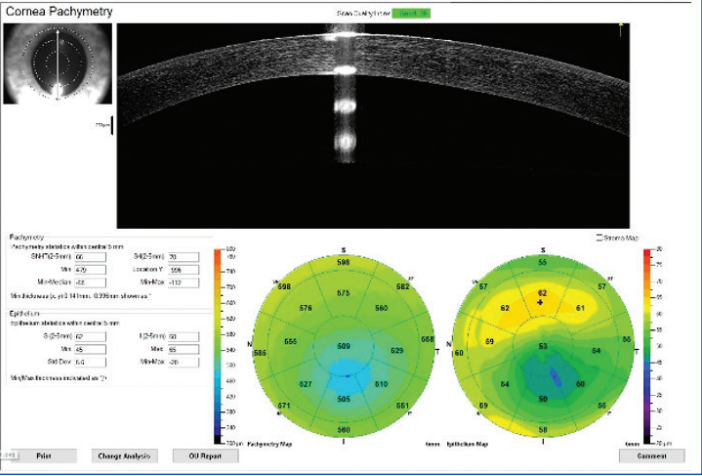
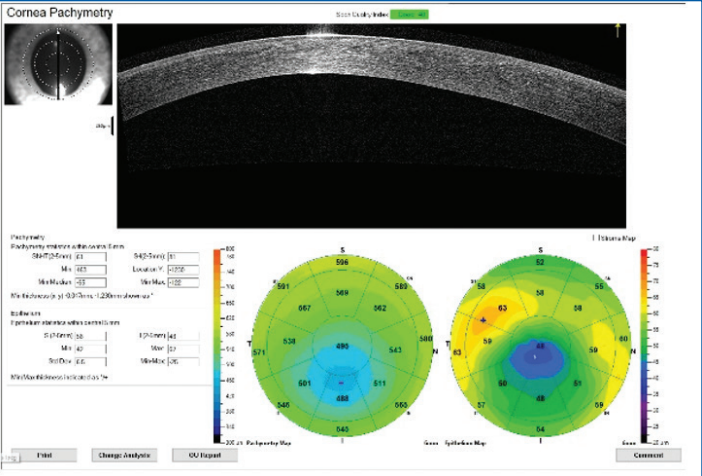
keratoconus, said Terry Kim, MD. “In the past, we only paid attention to the anterior surface curvature of the cornea, which is why all these types of publications have been revised to include that posterior corneal curvature,” he said. The Amsler-Krumeich classification system was recently revised to include posterior corneal changes. With Scheimpflug imaging devices, clinicians can examine the anterior and posterior elevation, which is extremely important in identifying early patterns of keratoconus, Dr. Kim explained.

On corneal tomography, red flags include the following: thinnest pachymetry less than 500 µm, anterior elevation greater than 10 to 15 µm, and posterior elevation greater than 15 to 20 µm.³⁻⁵

“I recently examined a few patients who presented with uncorrected 20/20 or 20/25 vision, and when I conducted corneal mapping with a tomographer, I found that they had keratoconus,” said Gloria Chiu, OD, FAAO.

In a patient in his early 30s with 20/30+ UCVA OD and 20/20 OS, Dr. Chiu explained that keratoconus was not as evident in the eye with better sight. On corneal tomography OS, the posterior elevation was +26, while anterior elevation was +8 with Kmax of only 43.2 D (Figure 1). In the fellow eye, he clearly had keratoconus on the anterior and posterior surfaces (Figure 2). “But the eye with 20/20 vision had keratoconus and still provided good uncorrected vision for so many years,” Dr. Chiu said. Keratoconus was not diagnosed until corneal tomography was performed.

Corneal tomography provides a broad pachymetry map, and the BAD (Belin/Ambrósio) scale is a helpful visual tool, Dr. Kim said. He explained that the scale is not a formal part of any ectasia risk classification system, but it provides additional information in the cumulative assessment of diagnosing keratoconus and determining the risk of ectasia with refractive surgery.



Figures 3 and 4. OCT scans of corneas with keratoconus.

“The BAD score seems to be very helpful in categorizing whether patients are normal, at risk, or at high risk for having keratoconus,” Dr. Trattler said.

“We all know that the thinnest part of the cornea should be relatively close to the center or the apex of a normally shaped aspheric cornea,” said Andrew S. Morgenstern, OD, FAAO. “Scheimpflug cameras can provide a global thickness image, so it can tell you the corneal thickness at specific points throughout the cornea.”

Dr. Morgenstern checks to be sure progression from the thinnest point in the cornea to the periphery has a smooth transition as it increases asymptotically in its thickness from center to periphery. “If it does not, that is an indicator that the patient may have keratoconus,” he said.

Another advantage of tomography is that it analyzes the patient versus normative patient data, Dr. Morgenstern said.

However, Dr. Donnenfeld, added, by using tomography and topography scores, clinicians can miss diseases such as pellucid marginal degeneration, which will not always register as keratoconus.

“In those patients, if you’re looking at the tomography or topography, you will see a lobster claw pattern with steepening

Courtesy of Mile Brujic, OD, FAAO



“There are numerous genes that are associated very strongly with keratoconus, some more than others, particularly those genes that are linked to collagen specifically.”

— Elizabeth Yeu, MD

located very far inferior,” Dr. Trattler said. “If the area of steepening is located toward the periphery of the cornea, the I-S ratio may not pick up the abnormality.”

“A number of patients have a central nipple cone, and, in those patients, I-S does not work very well to screen for keratoconus risk, but it is usually straightforward to diagnose pellucid marginal degeneration,” said Richard L. Lindstrom, MD. “It’s those central cones that can sometimes confuse you, but they will usually have steepening—particularly posterior and anterior steepening—with central corneal thinning with the classical pattern on topography. But I-S will not help you there.”

“These patients can be extremely challenging in that sometimes they do not have skew deviation,” Dr. Donnenfeld said. “It looks like a regular bowtie cylinder, but it’s a truncated cylinder, so the bowtie looks shortened. That’s the clue that you’re dealing with a central nipple truncated cone.”

OPTICAL COHERENCE TOMOGRAPHY

“Optical coherence tomography (OCT) is a nice diagnostic tool that only adds to the information we have and gives us more confidence or caution about proceeding with refractive surgery,” said Neda Shamie, MD (Figures 3 and 4).

“If the thinnest part of the cornea is eccentric to the central 3 mm, I suspect keratoconus especially if it correlates with the area of asymmetric steepening on corneal topography,” she continued. “The same is true with epithelial mapping. Sometimes the thinnest part of the cornea is still within the central area, but there may be an area of abnormal corneal topography steepening and an epithelial thickness pattern on OCT that hints at the area of early ectasia. In early keratoconus, the topographic changes and anterior curvature abnormalities could be so mild that epithelial thickness changes over a cone can hide the topographic patterns. A thinning of the epithelium over a mild cone will be captured as a false smooth surface topographic pattern over the cone, hindering our ability to detect early keratoconus.”

John D. Gelles, OD, emphasized that the resolution of OCT allows in-depth corneal layer analysis and that epithelial thickness is an important diagnostic factor in addition to overall corneal thickness.

“Epithelial thickness distribution is affected in keratoconus by displaying thinning over the corneal apex and thickening around the base,” Dr. Gelles said. “This epithelial masking effect results in a corneal surface shape that is more regular than the underlying stromal shape. There have also been several studies that have analyzed thinning of Bowman’s layer as well.”

“We have been using the keratoconus risk score table with our

anterior segment OCT or pachymetry scans and it has been an absolutely revealing instrument,” Dr. Brujic said. “This is something most clinicians with anterior segment OCT imaging have access to. If they have OCT, they often times have anterior segment OCT, so using some of these risk tables is a great way to capture and gather more information about risk moving forward.”

WAVEFRONT ABERROMETRY

Dr. Lindstrom performs wavefront aberrometry, which is included with his laser, on all refractive surgery patients. “Tomography/topography can be a little redundant, so I do not always perform both topography and tomography,” he said. He generally performs tomography and wavefront aberrometry.

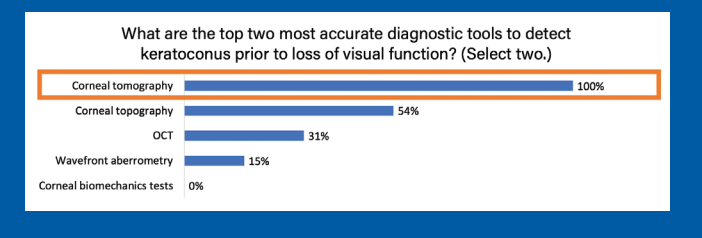
Higher coma on aberrometry makes him suspicious. “If you look at all keratoconus patients, they all have abnormally high coma, and where it starts to be meaningful is at about 0.6 μm RMS or higher,” Dr. Lindstrom said.

“Wavefront aberrometry on its own is a nonspecific but highly sensitive method of looking for abnormalities in the visual system, especially total higher-order aberrations, with aberrations of interest in the third, fourth, and fifth order,” Dr. Gelles said.^{6,7} “Most important in keratoconus are vertical coma and trefoil.”

He explained that when wavefront aberrometry is combined with Scheimpflug tomography or Placido disk topography, it allows the clinician to differentiate the origin of the aberrations. However, Dr. Gelles noted that tomography is the only true way to differentiate corneal from internal aberrations as tomography offers anterior and posterior corneal analysis, whereas Placido topography only analyzes the anterior surface, leaving any posterior corneal irregularities to be interpreted as internal aberrations.

CONSENSUS FINDING #5:

All panelists believe that corneal tomography is the most accurate diagnostic tool to detect keratoconus prior to loss of visual function.



Diagnostic Tool	Percentage
Corneal tomography	100%
Corneal topography	54%
OCT	31%
Wavefront aberrometry	15%
Corneal biomechanics tests	0%

CORNEAL BIOMECHANICS

Dr. Trattler explained that the strength (corneal biomechanics) of the cornea can be measured with the use of an ultra-high-speed Scheimpflug camera that evaluates the corneal deformation response of the cornea. A second technology, which measures the corneal hysteresis ocular response, can also provide information on the strength of the cornea. These technologies can help identify early keratoconus.

Dr. Gelles commented that although corneas with keratoconus are biomechanically weaker, there have been debates about the diagnostic value of corneal biomechanics metrics derived from certain devices in accurately differentiating normal from early keratoconus or identifying the change in biomechanics after corneal crosslinking. “This doesn’t mean the devices are not finding differences, just that the output metrics may not be accurately describing them,” Dr. Gelles said. He cited studies by Luz et al and Hallahan et al, which used custom-derived waveform metrics to show changes where the standard output metrics missed the changes.⁸

“Dynamic Scheimpflug waveform analysis offers significantly more information about corneal biomechanics, and derived multimetric analyses can produce risk scores,” Dr. Gelles continued. “As devices continue to evolve, we will have more and more comprehensive, sensitive, and specific methods of evaluating corneal biomechanics. I’m excited for the day Brillouin microscopy and OCT elastography make it to clinical practice.”

GENETIC TESTING

Genetic testing provides additional information about a patient’s risk of keratoconus.

“There are numerous genes that are associated very strongly with keratoconus,” Dr. Yeu said. “Some have stronger associations than others, particularly those genes that are linked specifically to collagen.”⁹

A new genetic test includes a 75-gene panel that analyzes more than 2,300 variants to identify the risk of keratoconus and a 70-variant panel to detect TGFBI corneal dystrophy. Variants are displayed with a risk score reference bar from 0 to 100. Each patient sample receives its own numeric risk score and determination of low to high risk. The test has been validated in more than 1,100 patient DNA samples in the United States.

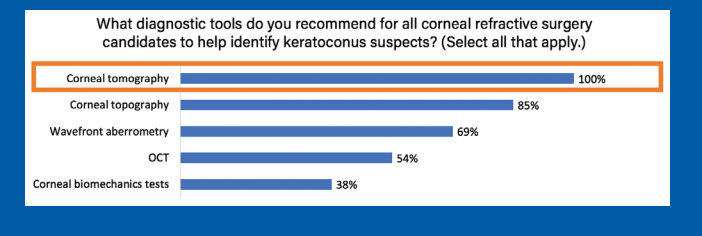
“This information is helpful as one piece,” Dr. Yeu said. “It’s unique. It gives you information that is inherent to the patient separate from the environment.”

Dr. Kim believes genetic testing is useful for patients who have a family member with keratoconus. “Ordering a genetic test in this scenario can inform our decision to say that the patient is a corneal refractive surgery candidate, to determine if they’re better suited for a surface ablation procedure, to follow the patient closer, and to look for early signs of keratoconus before a refractive procedure is performed,” Dr. Kim said. “It also helps in determining at a very early stage if this patient may benefit from corneal collagen crosslinking.”

Additional advantages are the lack of capital cost and space

CONSENSUS FINDING #6:

All panelists recommend corneal tomography for all corneal refractive surgery candidates to help identify keratoconus suspects.



Diagnostic Tool	Percentage
Corneal tomography	100%
Corneal topography	85%
Wavefront aberrometry	69%
OCT	54%
Corneal biomechanics tests	38%

requirements for this genetic test. “Giving full access to a test like this for all eyecare providers will change the way that we identify these risk factors for various corneal diseases,” Dr. Kim said.

According to Dr. Gelles, genetic testing can be used to assess the risk of keratoconus, with applications in children of patients with keratoconus, patients with questionable findings on corneal topography, refractive surgery candidates, and patients interested in myopia control.

“All of these are great applications of this test. It can aid in deciding whether or not corneal-based intervention is the ideal intervention and also aid in determining follow-up frequency based on risk for the disease,” he said.

“I see the power of this test as helping us identify patients early enough to get them into treatment soon enough, so that we’re not dealing with end-stage individuals,” Dr. Brujic said.

“Genetic testing has the opportunity to provide reassurance and hope to patients and their families with keratoconus, which will improve the vision-related quality of life over a patient’s lifetime,” Melissa Barnett, OD, FAAO, FSL, FBCLA, said.¹⁰

DEVELOPING DIAGNOSTIC STRATEGIES

“We have a lot of diagnostic tools that we can use to diagnose keratoconus, but I think the most important aspects still remain corneal tomography and corneal topography,” Dr. Donnenfeld said. “That’s where most of us spend our time.”

Recommended diagnostic devices depend on the stage of disease. “In moderately advanced cases, you can make that diagnosis even from the history of progressive refractive change, and so topography is likely sufficient,” Dr. Shamie said. “But as we push to detect earlier and earlier cases at risk to be able to intervene early, then tomography, OCT, and the more advanced diagnostics will help find those cases early in disease.”

In assessing refractive surgery patients, Dr. Morgenstern uses corneal tomography, wavefront aberrometry, and refraction to determine whether it is possible to obtain a sharp 20/20 visual acuity. “We are taking pictures and looking at what is today,” Dr. Morgenstern said. “Genetic testing is more a predictor of what is to come, so that will help us a lot.”

“Having a multitude of different diagnostic modalities at our

fingertips is extremely important, including topography and/or tomography (which is extremely important in early cases),” said Ashley Brissette, MD. “Some newer modalities such as corneal biomechanical testing and even epithelial mapping are extremely useful. Genetic testing fits nicely into that because we know that inheritance is a component of this disease.”

“Any time that we have suspicious findings, we want to go a little bit further,” Dr. Gelles said. He and his colleagues studied approximately 1,000 eyes with keratoconus, analyzing their manifest refractions. Most eyes had against-the-rule or oblique astigmatism, and myopia present was not as high as suggested by the Amsler-Krumeich grading scale, which he noted was extremely outdated.¹¹

“Although the data is in prepublication, our findings suggest corneal or refractive, against-the-rule or oblique astigmatism greater than 1.50 D should warrant additional testing such as corneal topography or tomography,” he said. “Practitioners without these diagnostic instruments should refer to colleagues with advanced testing for screening. Additionally, genetic testing has value in these situations for practitioners to understand risk in patients with subtle questionable findings.”

Consensus Finding #5 revealed that all faculty members believe corneal tomography is the most accurate diagnostic tool to detect keratoconus before loss of visual function.

According to **Consensus Finding #6**, all panelists recommend corneal tomography for all corneal refractive surgery candidates to help identify keratoconus suspects.

TACKLING KERATOCONUS

Diagnostic devices and tests are increasing clinicians’ understanding of keratoconus. “As we have incorporated more and more sensitive diagnostic technologies, cases that we would term ‘unilateral keratoconus’ are becoming fewer and far between,” Dr. Eiden said.

The assurance that keratoconus is a bilateral disease is borne out by genetic testing, which evaluates patients for a disease, Dr. Morgenstern explained. Genetic testing does not test only one eye.

Dr. Eiden emphasized that the greatest challenge is getting more sensitive technologies into the hands of primary eyecare providers. “Until they are, there will still be many patients who go on to progress in their keratoconus to a point at which it negatively impacts their visual function before they are diagnosed,” Dr. Eiden said.

Dr. Barnett encouraged practices that do not have corneal topography to investigate cost-effective combination systems that are available. “There are systems that include dry eye diagnostic capabilities and guidance for specialty contact lens fitting in addition to corneal topography,” she said. Dr. Barnett added that more cost-effective options also would increase accessibility to more sensitive imaging for practitioners beyond the United States.

“We have a number of multifunctional instruments and one of them incorporates autorefraction, aberrometry, and Placido topography all in one,” Dr. Eiden said. “In every patient who is autorefracted for a routine eye exam, we will be able to look at topography, assess their higher-order aberration levels, and therefore, we

are running these kinds of measurements on much higher numbers of patients. With multifunctional instruments that could serve as screeners in our practices, we will be able to detect these types of patients much earlier in the continuum of the disease.”

“Over time, we have seen the evolution of quantitative indices for corneal analysis, aiding in keratoconus and ectasia detection,” Dr. Gelles said. “Some of the first were derived using multiple factors from the anterior corneal surface via Placido topography. Then with corneal tomography, multiple corneal factors, such as anterior and posterior elevation and corneal thickness, can be combined as a diagnostic aid.”

“The same multimetric concept has been applied to create biomechanical indices with multimetric corneal biomechanical factors,” Dr. Gelles continued. “This culminated in the combination of biomechanical indices with tomographic indices to create even more sensitive and specific risk analysis. Many of these indices are product specific. The future is in universal artificial intelligence for the combined analysis of tomography, biomechanics, aberrometry, and genetics for the ultimate risk analysis.”

CONCLUSION

“As we continue to understand this complex disease, be open to embracing new technology that will allow us improved diagnostics. It also offers a service to our patients to provide them with the best care that we can and guide them in their decision-making for certain surgical procedures,” Dr. Brissette said.

“Genetic testing is not only going to include keratoconus testing, but it also has included testing for the TGF-β stromal dystrophies,” Dr. Kim said. He participated in a large clinical trial showing an especially high prevalence of stromal dystrophies in Asia and traveled to South Korea to examine one of the largest series of refractive surgery-exacerbated stromal dystrophies.

“I’ve seen the impact of tests like these in preventing these complications in many patients, which is important because these are sight-threatening conditions, as is keratoconus,” he said. “I am excited that we’re going to see a paradigm shift in terms of what we are doing in our clinics to identify corneal diseases as early as possible, help prevent vision loss, and improve the quality of life for our patients.”

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GENETIC TESTING: GUIDANCE IN REFRACTIVE SURGERY

Genetic testing results add to the body of information gathered from classical tests to detect keratoconus. Faculty members believe it is a useful tool in refractive surgery patients.

“We do not fully understand exactly what specific risk factors contribute to keratoconus,” said Ashley Brissette, MD. “There are multiple factors. Because of that, we need multiple modalities for investigation to establish and diagnose risk for keratoconus.”

Dr. Brissette believes genetic testing fits in well with available tests. “In the past, we didn’t have a way of understanding the impact of genetics on this disease other than asking about family history, which some patients might not know or completely understand,” she said.

“Genetic testing plus the supplementing of the technologies that we have in our practice will give us almost all of the information we need to set up what I consider the most appropriate treatment strategies and plans for patients moving forward,” said Mile Brujic, OD, FAAO. “Ultimately, it gives us another piece of information for those individuals who may have higher risk and lower initial corneal findings or those individuals who may have a lower risk and some mild, subtle findings on the cornea.”

“Patients with no corneal findings can definitely go on to develop keratoconus,” said Gloria Chiu, OD, FAAO. “It’s our mission to identify these findings as early as possible. When we start to see the signs on their cornea through the slit lamp, it’s often too late. I think genetic testing is very exciting and it brings me a sense of relief.”

GENETIC TESTING IN REFRACTIVE SURGERY CANDIDATES

According to **Consensus Finding #7**, on average, 11% of all corneal refractive surgery candidates are likely to be identified as keratoconus suspects before surgery. Of the panelists, 10 of 13 believe that more than 5% of all corneal refractive surgery candidates are likely to be identified as keratoconus suspects before surgery.

In addition, S. Barry Eiden, OD, FAAO, believes percentages may be impacted by referring practitioners.

“For example, if your refractive surgery center is based upon referrals from a highly educated and aware group of referring doctors, that number is going to be lower,” Dr. Eiden said.

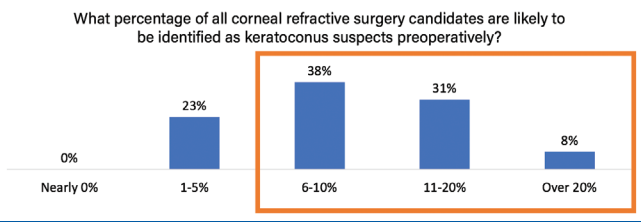
“The time to do genetic testing is when it might change what you do,” said Richard L. Lindstrom, MD.

Dr. Lindstrom explained that 10% to 12% of refractive surgery candidates have results from diagnostics that discourage surgeons from performing corneal refractive surgery, whereas frank keratoconus will develop in only approximately 0.5 to 1%.

“It would be useful to have something else to either encourage us and our patients that it might be safe to treat, or to encourage us that we should not treat,” Dr. Lindstrom said. “That’s where something like genetic testing might be useful.”

CONSENSUS FINDING #7:

- On average, 11% of all corneal refractive surgery candidates are likely to be identified as keratoconus suspects preoperatively.
- Ten of 13 believe that more than 5% of all corneal refractive surgery candidates are likely to be identified as keratoconus suspects preoperatively.



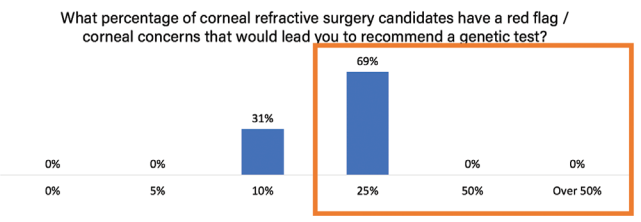
Terry Kim, MD, is particularly concerned about high corneal curvature, with K exceeding 47.00 D. “We have become more selective in our patients,” he said. “For instance, we have moved from using a residual stromal bed of 250 μm to using 300 μm. As far as thinner corneal pachymetry, some surgeons are not doing LASIK on patients who have lower than a 500-μm central pachymetry.” Dr. Kim believes genetic testing complements traditional testing in these cases, especially in addressing family members with keratoconus.

Genetic testing also may guide choice of refractive surgery procedure.

“We see many patients who tell us they only want to have LASIK. They do not want to have PRK,” said Eric D. Donnenfeld, MD. “They may be borderline candidates in certain criteria, such as they may have completely normal topographies, but their corneas may be a little thin. Having genetic markers to aid us in

CONSENSUS FINDING #8:

- On average, 20% of corneal refractive surgery candidates have red flags/corneal concerns that would lead doctors to recommend a genetic test.
- Nine of 13 believe that at least 25% of corneal refractive surgery candidates have red flags/corneal concerns that would lead doctors to recommend a genetic test.





“When we start to see the signs on their cornea through the slit lamp, it’s often too late.”

— Gloria Chiu, OD, FAAO

deciding who can go on to LASIK and who should have PRK or who should have no surgery at all I think will be very helpful.”

In addition, William B. Trattler, MD, said, it could be helpful in cases where patients have keratoconus in one eye while the fellow eye is normal. “We know that we want to avoid LASIK on that patient because they are at high risk for developing keratoconus,” he said. “If we had a genetic test that could prove that genetically this patient is at risk, it could help us.”

In addition, Dr. Trattler said, there are many patients in whom both eyes appear to be normal, but keratoconus has not yet manifested, so the genetic test would also be helpful in those cases.

“The military does refractive surgery on very young patients,” Dr. Donnenfeld said. “These are 18-, 19-, 20-year-olds having refractive surgery. Those are the patients that I’m most concerned about: the ones who come in for surgery because you don’t know if they are going to develop keratoconus. The 30-year-olds we see in private practice are a very different group of patients.”

ADVANCED CARE

Every refractive practice does not have a full range of diagnostic tests, including biomechanics, corneal hysteresis, optical coherence tomography, and corneal epithelial mapping, explained Elizabeth Yeu, MD.

“To be able to have that extra bit of knowledge that genetic testing can offer can provide greater confidence in what the surgeon can recommend to the patient,” she said.

According to **Consensus Finding #8**, on average, 20% of

CONSENSUS FINDING #9:

- On average, 94% of corneal refractive surgery candidates who are keratoconus suspects would receive a genetic test.
- Twelve of 13 believe that all corneal refractive surgery candidates who are keratoconus suspects should receive a genetic test.

What percentage of corneal refractive surgery candidates, who are keratoconus suspects, would you consider doing genetic testing on?

Percentage of candidates	Percentage of respondents
0%	0%
25%	8%
50%	0%
75%	0%
100%	92%

corneal refractive surgery candidates have red flags or corneal concerns that would lead doctors to recommend a genetic test.

Among the panelists, 9 of 13 believe that at least 25% of corneal refractive surgery candidates have red flags or corneal concerns that would lead doctors to recommend a genetic test.

“Regardless of the level of technologies that a clinician has in their practice, everybody has a place for genetic testing in the discussion of this with their patients based on what they are currently seeing in their practices and their suspicion for genetic susceptibility to keratoconus,” Dr. Brujic said. He would recommend genetic testing to supplement data from advanced testing for patients with progressive myopia coupled with against-the-rule or oblique astigmatism that is shifting or progressing.

According to **Consensus Finding #9**, on average, 94% of corneal refractive surgery candidates who are keratoconus suspects would receive a genetic test. Twelve of 13 panelists believe all corneal refractive surgery candidates who are keratoconus suspects should receive a genetic test.

“To me, it would be my responsibility if I have this test in my armamentarium that I would at least make it available, not required, to every patient considering corneal refractive surgery,” Dr. Eiden said.

Dr. Kim added that genetic testing will also help identify patients with very early or no signs of keratoconus who would be good candidates for corneal collagen crosslinking to help halt any progression of disease. In addition, he said, surgeons are combining crosslinking with PRK or LASIK procedures, which he has done with a sequential but not a simultaneous approach.¹

“I think this is going to be the trend,” Dr. Kim said. “Identifying the need to perform crosslinking earlier is going to help us increase awareness of keratoconus diagnosis and prevent the incidence of refractive surgery-induced ectasia.”

Dr. Trattler has concerns about combining crosslinking with PRK at the same time, as there is an increased risk for developing postoperative haze. “Instead, you can perform the procedures sequentially. For example, you can perform crosslinking and then 6 months later perform PRK or vice versa, do PRK first and then crosslinking 6 months later,” Dr. Trattler said. “This reduces the risk for experiencing significant haze, which can impact vision.”

Neda Shamie, MD, believes genetic testing will cause a paradigm shift in managing these patients. For example, she explained, if a young patient is a strong candidate on other diagnostic testing but their genetic testing puts them at mild to moderate risk, the doctor can have a discussion with the patient regarding their genetic risk and, fully informed, could still likely proceed with LASIK but advise close follow-up.

“If there is any shift in refraction in the postoperative period, and especially if any suspicious change is noted on corneal topography, suspicion for ectasia would be high and treatment in the form of crosslinking would be initiated early before vision changes become clinically significant,” she said.

Dr. Shamie believes that in its current form, combining LASIK or PRK with crosslinking leaves too much uncertainty about outcomes. “The change in corneal curvatures and related shift in refractive error with crosslinking creates a sense of a ‘moving target’ when LASIK and PRK rely on stability and precision for best outcomes,” she said. “Furthermore, the risk for haze and delaying healing when PRK is combined with crosslinking gives me pause in considering it as an option for patients until more studies prove its efficacy and safety.”

CONCLUSIONS

“Genetic testing allows us to have more information to provide to our patients,” Dr. Brissette said. “I believe genetic testing comes into play to increase our ability to offer this vision-changing procedure to patients who want this done in a safe way and to provide them more information about their risk of having a complication.”

Dr. Brissette explained that patients will appreciate the guidance in decision-making that genetic testing provides. “I think they will look toward your practice as being one of the top practices if you’re offering the most advanced testing,” she said.

“The diagnostic tools that we have used thus far have all looked at the sequela of the disease, not the underlying cause,” Dr. Shamie said. “The missing link has been finding the underlying risk factors, with an important one being the genetic predilection of developing the disease. If genetic testing can help me do a better job in risk stratification as a refractive surgeon and possibly give me pause in offering a corneal-based procedure and instead recommend an implantable collamer lens in an at-risk patient, I have done what I need to do in offering the best and safest option for my patient.”

1. Kanellopoulos AJ. Comparison of sequential vs same-day simultaneous collagen cross-linking and topography-guided PRK for treatment of keratoconus. *J Refract Surg.* 2009;25(9):S812-S818.

GENETIC TESTING: GUIDANCE FOR KERATOCONUS TREATMENTS

Faculty agreed that genetic testing can play a key role in assessing a patient’s risk of keratoconus and choosing a treatment plan.

“Another role genetic testing could play would be to help me decide how frequently to monitor a patient on return visits for early signs of keratoconus,” said Richard L. Lindstrom, MD.

Terry Kim, MD, believes genetic testing for keratoconus could be a potential practice builder.

“The strongest evidence we have for the genetic basis of

keratoconus is the evidence we have seen in monozygotic twins in terms of the concordance of disease we see,” he said. “But if you take a patient whose test results indicate a high risk for keratoconus, then I think you’re going to be obligated to at least get their first-order relatives in to be tested and screened.” Dr. Kim stressed that the goal is to identify patients earlier so clinicians can prevent disease progression and complications from surgical procedures.

GUIDING TREATMENT STRATEGIES

With the approval of a corneal crosslinking procedure in the United States for progressive keratoconus and corneal ectasia after refractive surgery, clinicians have a new treatment option to offer patients that can slow or halt progression of the disease.

Eric D. Donnenfeld, MD, explained that it would be helpful if a positive genetic test combined with the finding of any corneal irregularity in a young patient would enable insurance coverage for corneal crosslinking, rather than waiting for the disease to show progression.

Additionally, although most eyecare professionals do not have corneal topography, everyone will have access to genetic testing. “For some of these practices, it may be very reasonable to perform genetic testing on patients at risk and have those patients followed by a corneal specialist so that they can have a diagnosis made earlier rather than waiting for them to develop overt disease,” Dr. Donnenfeld said.

“Furthermore, it guides us as to whether we should perform corneal crosslinking now or send patients for therapeutic treatments for their vision with different kinds of contact lenses or orthokeratology or what we need to do to take care of them,” said Elizabeth Yeu, MD.

She explained that therapeutic contact lenses mask the corneal curvature. “Understanding what their genetic predisposition is will help us to better direct whether or not we need to do something on the front end before we can also take care of them and help them with their high astigmatism, progressive myopia on the medical refractive side of it,” Dr. Yeu said.

COORDINATING TREATMENT

“Historically, patients with keratoconus have been treated in silos in eyecare and eyecare practitioners often approached these patients with their individual clinical biases,” said S. Barry Eiden, OD, FAAO. “I’ve seen many patients who have been in practices where they have just been fit in contact lens after contact lens as their condition continues to progress and no mention to these patients that there is even a treatment to control progression. I have also seen patients who have gone to practices that can easily be managed for vision correction with contact lenses who have been told they should have a corneal transplant.” Therefore, appropriate management would take a comprehensive approach, integrating vision correction and disease progression management, he said.

“When I see keratoconus patients, the first thing on my mind is, what is their age and what disease stage are they in? Is there



“We live in a time where we now have a treatment to stop progression of this disease and that changes the onus to the practitioner to find the disease as soon as possible.”

— John D. Gelles, OD

still an opportunity to intervene with corneal crosslinking? Second is, are they getting best corrected vision?” said Gloria Chiu, OD, FAAO. “That’s where I will fit them with glasses or the contact lens modality that is best suited for them and their lifestyle.”

If surgery is required, Dr. Chiu sends the patient to the corneal specialist. “Everybody’s role is important, and you have to remember that there are other people who can help and that you cannot do it all alone,” she said.

Mile Brujic, OD, FAAO, who works in a primary care optometric setting, explained that the first step is identifying patients with keratoconus who are unaware of why their vision is not optimized when using their glasses or soft contact lenses.

The next step, Dr. Brujic said, is discussing the patient’s options. “If we’re talking about a 60-year-old man who has known he’s had keratoconus for the last 40 years, that is going to be a different conversation than an individual who is 14 years old and wants to start wearing contact lenses and we incidentally find that the patient has keratoconus,” he said.

John D. Gelles, OD, explained that clinicians need to focus on a three-step process: “Diagnose early, halt progression, and then improve vision. Proper management of keratoconus is a truly collaborative effort between the MD and OD,” he said.

“Improving visual acuity in these patients is also collaborative and must address the comprehensive visual needs of the patient,” Dr. Gelles continued. “The best visual acuity possible will be achieved with a variety of specialty contact lenses, while improved uncorrected and spectacle-corrected visual acuity is addressed by a variety of surgical interventions. That’s where we see the blend between the various options and the importance of collaboration. For each patient, the solution is going to be different, and utilizing both strategies can make patients more functional in all situations.”

“We tell patients about the importance of vision correction, that’s typically with contact lenses; disease progression control with corneal crosslinking; and finally, the potential to reduce the severity of the disease, which is intrastromal corneal ring segments or topography-guided PRK,” Dr. Eiden said. “The last option is keratoplasty for those who have exhausted the other options.”

CONCLUSIONS

“To have an opportunity to take advantage of a diagnostic tool in genetic testing, to do risk stratification for our refractive patients, and to be able to detect early keratoconus so we can offer crosslinking earlier rather than later makes sense,” said Neda Shamie, MD. “It brings us full circle in offering patients a much

more comprehensive approach for keratoconus treatment as well as a safer and more thoughtful approach for refractive surgery.”

“The benefit of genetic testing is providing a level of risk that the patient will have to developing keratoconus, in particular, for young patients who may not have signs yet, particularly for patients with questionable findings and we are looking for another piece of information to help optimize their long-term visual health,” Dr. Brujic said. “This is going to empower clinicians to make the best decisions for their patients and for the best visual outcomes over their lifetime.”

“We live in a time where we now have a treatment to stop progression of this disease and that changes the onus to the practitioner to find the disease as soon as possible,” Dr. Gelles said. “Genetic testing may prove to be the most impactful test in early diagnosis.”

WEIGHING KERATOCONUS TREATMENTS

Specialty contact lenses such as scleral lenses are often used to improve vision in patients with keratoconus.

“I think there is a tendency to improve the vision of these patients first...but then potentially overlook the presence of an underlying progressive disease that can be treated in terms of actually halting the progression,” said Terry Kim, MD. “It is an important awareness step to make sure you actually treat the underlying disease first in terms of halting the progression before fitting these patients with glasses or contact lenses.”

In borderline patients, said Elizabeth Yeu, MD, patients may need corneal collagen crosslinking and then staged topography-guided PRK; ICLs are the default option for myopic patients younger than 45 years of age who have good BSCVA potential and have been ruled out for corneal refractive surgery.

“I have performed a few PRK procedures after crosslinking and I am still following those patients. I know this can be effective,” Dr. Yeu said. “Patients may not progress, but I’m fairly conservative. I perform crosslinking and medically manage.”

“The toric ICL has been very helpful in some of these patients who have somewhat stable keratoconus, with their central cornea having a symmetric bowtie after crosslinking,” said Neda Shamie, MD. “I think toric ICLs are a very safe option for these patients.”

“If a patient has progressive keratoconus, I crosslink at the earliest possible date,” said Richard L. Lindstrom, MD. “I think

that is the global consensus—if you write keratoconus on the chart and they’re young and likely to progress or have progressed, they deserve to be crosslinked.”

Dr. Lindstrom explained that he is comfortable with so-called “refractive crosslinking.”

“If the patient is highly motivated to not only have keratoconus stabilized but have their refractive error improved upon, I’ve had good results with intracorneal rings and also with PRK,” he said. “I prefer to do intracorneal rings 2 to 4 weeks before crosslinking and PRK 12 to 18 months after crosslinking. That has worked well for me for select patients with good informed consent.”

“Topographic lasers have made a significant improvement in our ability to manage these patients,” said Eric D. Donnenfeld, MD. “In a lot of patients in the past in whom I was considering doing transplantation, I can now rehabilitate with a topographic laser after they’ve been crosslinked.” He performs it sequentially; he does not perform crosslinking and refractive surgery at the same time.

Dr. Kim first uses crosslinking to halt disease progression and then considers intracorneal ring segments off-label to help improve contact lens fitting if needed.

“I do not like to treat the refractive error in patients who have keratoconus with PRK first,” he said. “This has been reported in the literature.¹ But I certainly feel more comfortable if they have already had a crosslinking treatment where I’m more confident that their cornea is going to be stable and their refraction is going to be more reliable.”

Dr. Shamie added that she does not like to perform PRK on patients who have had keratoconus unless they are older and have demonstrated stability because keratoconus is unpredictable and unstable. “We know even a very peripheral limbal relaxing incision can destabilize these corneas,” she said. “It’s hard to imagine PRK will not potentially destabilize them.”

However, said William B. Trattler, MD, it depends on the level of keratoconus. “If they have mild keratoconus and their corneal shape has improved following crosslinking, then performing PRK for a small refractive error is safe in my experience,” he said. “We can still follow them and consider repeating the crosslinking procedure if they were to progress in the future.”

On the other hand, Dr. Shamie asserted that it is difficult to perform a risk stratification in a 21-year-old patient. “I think age has a lot to do with it, the degree of keratoconus, how progressive it has been, and now, with genetic testing, having more of that information,” she said.

“It’s nice that we now have the option of a deep anterior lamellar keratoplasty (DALK) procedure to minimize the risks of graft dehiscence and graft rejection associated with a full-thickness keratoplasty procedure,” Dr. Kim said. “We’re fortunate to have a lot of surgical treatment options for the more advanced keratoconus cases.”

Dr. Donnenfeld is frustrated when young patients need to be treated with penetrating keratoplasty or DALK. “We need to diagnose these patients earlier and manage and crosslink them

sooner,” he said. “My hope would be that eventually, penetrating keratoplasty and DALK for keratoconus will become like polio. They will cease to exist as we have better treatments that allow us to stop the progression of the disease.”

1. Kanellopoulos AJ. Comparison of sequential vs same-day simultaneous collagen cross-linking and topography-guided PRK for treatment of keratoconus. *J Refract Surg.* 2009;25(9):S812-S818.

IMPACT OF KERATOCONUS ON PATIENTS AND PRACTICES

Clinicians can significantly help patients experiencing the effects of keratoconus (Figure 1).

INFLUENCE ON PATIENTS’ LIVES

“I have followed patients for decades with keratoconus, and there’s no doubt in my mind that keratoconus has a profound effect not only on the physical but also the psychosocial aspects of these patients’ lives,” said Eric D. Donnenfeld, MD.

Elizabeth Yeu, MD, emphasized that advanced keratoconus affects work productivity because patients’ vision is affected, they cannot tolerate contact lenses, or they need surgery.

“Many patients do not realize they have this condition,” said William B. Trattler, MD. “They think their vision has deteriorated because they are getting older. That is a common reason that we have this delay in the diagnosis of keratoconus. Patients will not realize they have a problem until their keratoconus advances to a level where they have visual symptoms like ghosting or experience actual visual loss. At this point, the level of keratoconus is often quite advanced.”

The key, he said, is for eye care providers to be more proactive and perform screening topographies more frequently, just like they routinely measure eye pressure in all patients prior to the onset of the signs or symptoms of glaucoma.

TAKING AIM IN CLINICAL PRACTICE

“The work we do as eye doctors in our clinical practice can better the lives of our patients,” said Melissa Barnett, OD, FAAO, FSLs, FBCLA. “One of the most important aspects of our job is listening, counseling, being empathetic, and providing valuable sources of information such as the National Keratoconus Foundation, which has a multitude of resources, including support groups for patients with keratoconus.”

Dr. Barnett described an 18-year-old patient who had crosslinking and could not complete her studies because of 20/200 vision; after the scleral lens fitting, she was 20/20 in each eye.

“The combination of crosslinking and scleral lenses completely changed her life. She is now in school, excelling in her studies, and able to be independent and drive,” she said.

“We can’t forget the importance of collaborative care with other providers and to refer amongst our colleagues as well.”

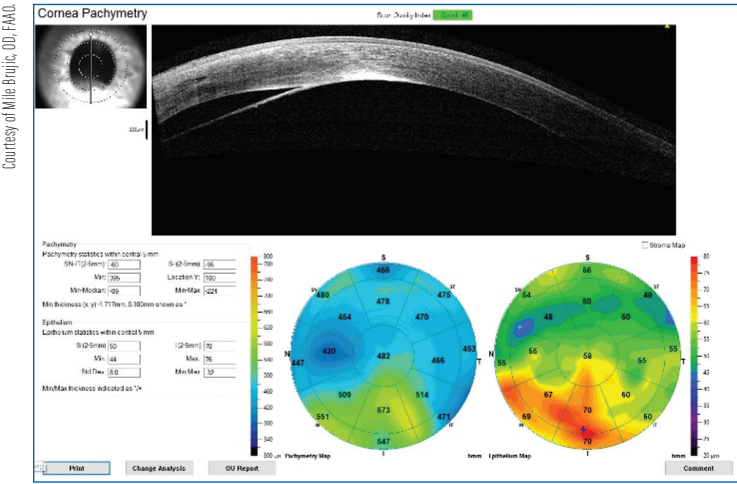


Figure 1. Optical coherence tomography scan of the cornea of a patient with keratoconus showing corneal hydrops.

Dr. Barnett said. “It is essential to consider specialty contact lenses prior to corneal transplantation. If you don’t fit specialty contact lenses in your practice, refer to someone who does for those services. The collaborative care approach is ideal to provide the best outcome for each individual, along with achieving patient loyalty.”

EXPANDING UNDERSTANDING

According to **Consensus Finding #10**, nine of 13 panelists believe the average corneal refractive surgery candidate is not at all informed about keratoconus and related risk factors.

According to Dr. Yeu, concerns about ectasia, as well as lack of training and decreases in refractive surgery volumes, may be causing fewer surgeons to perform refractive surgeries.¹ “For a multitude of reasons, most surgeons are not doing a very high volume of refractive surgery, and a lot of surgeons are not doing it at all,” she said.

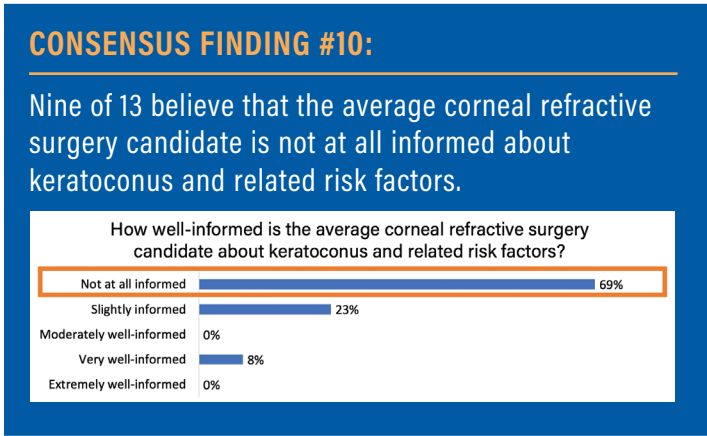
Ashley Brissette, MD, explained that during her cornea fellowship, there was significant fear of potential risk factors. “I think what ends up happening is that we become very conservative surgeons because we do not want to create harm,” she said.

“Even though the risk of ectasia is very low and the incidence is extremely low, the reality is for that individual, ectasia is extremely impactful to their life,” said John D. Gelles, OD.

Neda Shamie, MD, explained that refractive surgeons take every step possible in risk stratification. “But our ability to do a very accurate risk stratification is not perfect,” she said. “I think there will be cases that will still develop ectasia even if stratified on the lower end of risk with genetic testing as environmental factors are still at play.”

“It can just happen despite patients having no risk factors prior to corneal refractive surgery,” Dr. Trattler said.

Dr. Brissette added that the fear of keratoconus developing after refractive surgery affects surgeons’ confidence. “Now that



we have more diagnostics available, even now with this genetic testing, it’s something else that we can add to our list of tests so we can develop that confidence to properly educate patients and confidently make recommendations that we think will be best for their vision and health,” she said.

For younger patients in their teens and 20s, Gloria Chiu, OD, FAAO, suggested that all of the patient’s siblings be tested for keratoconus. “Even though a family member has keratoconus, do not assume that they have educated everybody else about their own condition,” she said.

She also recommended that adults with keratoconus have all of their children tested. “If we can detect the risk and send these patients for treatment, such as with corneal crosslinking, we will prevent a lot of visually debilitating corneal changes that happen in the more advanced stages,” Dr. Chiu said.

In addition, said Andrew S. Morgenstern, OD, FAAO, genetic testing will change his routine care and follow-up schedule, influence him to be more aggressive in evaluating certain tests, and prompt him to ask different questions regarding the patient history and perform different tests. “I might do a point spread function wavefront aberrometry on an 11-year-old where I typically wouldn’t before, so it is going to make it a more personalized experience.”

Dr. Barnett has been discussing genetic testing for keratoconus with her patients. “I would encourage everyone to discuss genetic testing because my patients have been so interested, especially for their children and families,” she said.

IMPACT ON REFERRAL PATTERNS

“Practices that provide scleral lenses to keratoconus patients as well as practices that perform crosslinking all work together to help patients who are diagnosed with keratoconus. It is helpful for eye care providers to be aware of the practices in their community that focus on caring for patients with keratoconus, as prompt referrals can allow keratoconus patients to receive treatment sooner,” Dr. Trattler said.

Much more education about keratoconus is available in some areas compared with others, Dr. Yeu said. As a result, some

“Practices that provide scleral lenses to keratoconus patients as well as practices that perform crosslinking all work together to help patients who are diagnosed with keratoconus.”

— William B. Trattler, MD

practices may receive referrals for potential crosslinking when progression is occurring and BCVA cannot be achieved with glasses and the patient requires therapeutic contact lenses.

“Those are the patients that need to be referred. The earlier the better,” Dr. Yeu said. “Or they may require changes because their fit is not right. All of those are subtle symptoms that they are progressing in their keratoconus even if curvature is not demonstrating it because their curvature has been masked.”

“Having a genetic marker that allows us to quantitate the risk for these patients may convince a lot of referring doctors that it is okay to have refractive surgery at an earlier age because the patient does not have significant risk for developing ectatic disease,” Dr. Donnenfeld said.

According to **Consensus Finding #11**, nine of 13 panelists believe the fear of patients developing keratoconus is very and extremely significant for the doctor’s decisions pertaining to corneal refractive surgery.

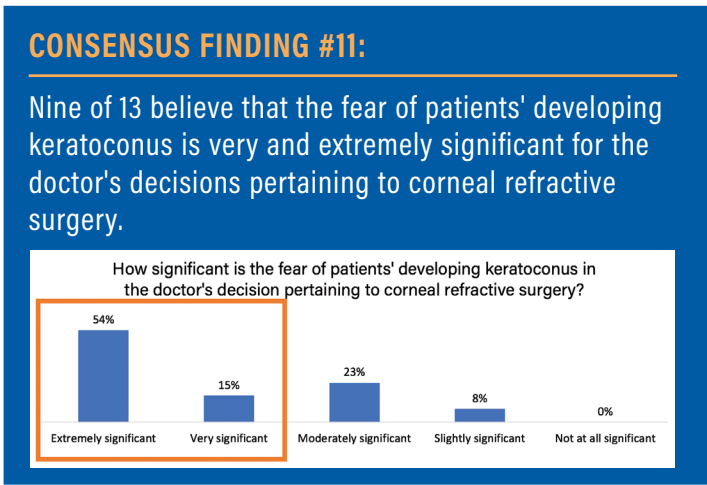
The news media widely covered the complications of early corneal refractive surgery, pushing it to the forefront of people’s minds, Dr. Morgenstern noted. At that time, clinicians did not have advanced technology that is available today.

“Then we got a lot better because our technology got better and reduced those complications,” he said.

Dr. Donnenfeld explained that every refractive surgery candidate has some level of fear, with some being more fearful than others. “The question is, if you could reduce the fear factor, how many more patients would be coming into our offices if they had a little bit more comfort in the procedure?” he said.

CONCLUSIONS

“We know that we should implement an early intervention as best as possible with genetic testing for keratoconus, especially if there is a family history, if you want to see if that offspring has the disease,” Dr. Morgenstern said.



Beyond that, he explained, clinicians need to listen to their patients and strenuously address early intervention. “Stopping it as soon as possible and saving vision is what our job is,” Dr. Morgenstern said.

“Keratoconus affects not only an individual but also their family and community,” Dr. Barnett said. “With this ability to diagnose and manage early, we can improve the patient’s quality of life, improve the economic burden for their entire lives, and give them independence.”

“Today, we have technologies that allow us to detect the disease earlier along its continuum,” said S. Barry Eiden, OD, FAAO. “Coupling that with our ability to control progression of keratoconus, we can now preserve visual function and improve patients’ lives. The introduction of genetic testing for keratoconus further adds to our armamentarium.” ■

1. Yeu E, Reeves SW, Wang L, Randleman JB; ASCRS Young Physicians and Residents Clinical Committee. Resident surgical experience with lens and corneal refractive surgery: survey of the ASCRS Young Physicians and Residents Membership. *J Cataract Refract Surg.* 2013;39(2):279-284.

KERATOCONUS TESTING CONSENSUS STATEMENT:
UNDERSTANDING THE INCIDENCE AND IMPACT OF KERATOCONUS IN CORNEAL
REFRACTIVE SURGERY & REVIEWING NEW STANDARDS TO PREEMPTIVELY IDENTIFY THESE PATIENTS

CME Release Date: August 2021
COPE Release Date: July 26, 2021
COPE Expiration Date: July 21, 2023

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License Number _____ OE Tracker Number _____

DEMOGRAPHIC INFORMATION

Profession	Years in Practice	Patients Seen Per Week (with the disease targeted in this activity)	Region
___ MD/DO	___ >20	___ 0	___ Northeast
___ OD	___ 11-20	___ 1-15	___ Northwest
___ NP	___ 6-10	___ 16-30	___ Midwest
___ Nurse/APN	___ 1-5	___ 31-50	___ Southeast
___ PA	___ <1	___ >50	___ Southwest
___ Other			

LEARNING OBJECTIVES

Did the program meet the following educational objectives?	Agree	Neutral	Disagree
Define etiology and progression of keratoconus, understand how refractive surgery can exacerbate these conditions, and review the impact this has on visual outcomes and quality of life	_____	_____	_____
Describe the prevalence of the refractive surgery patients developing keratoconus in various patient populations	_____	_____	_____
Identify the accuracy of various conventional and new genetic testing metrics for identifying refractive surgery patients who may be at risk for developing keratoconus	_____	_____	_____
Recommend diagnostic work-up protocols and pre-emptive testing indications for various groups of refractive surgery patients to maximize the diagnosis of keratoconus suspects	_____	_____	_____
Review treatment options for refractive surgery candidates who have or are likely to develop keratoconus	_____	_____	_____

PLEASE COMPLETE AT THE CONCLUSION OF THE PROGRAM.

POSTTEST QUESTIONS

1. Based on this activity, please rate your confidence in your ability to understand how refractive surgery can exacerbate the progression of keratoconus (based on a scale of 1 to 5, with 1 being not at all confident and 5 being extremely confident).

A. 1
B. 2
C. 3
D. 4
E. 5
2. Which of the following were/was reported to be mandatory finding/s to diagnose keratoconus according to the 2015 Global Consensus on Keratoconus and Ectatic Disease?

A. Clinically inflammatory corneal thickening
B. Abnormal posterior ectasia
C. Abnormal corneal thickness distribution
D. B & C
3. When discussing keratoconus, clinicians probably would NOT ask the patient about _____.

A. Eye rubbing
B. Usual sleeping position
C. Family history
D. Lid hygiene
4. _____ was reported to be a risk factor for keratoconus.

A. Elevated intraocular pressure
B. Diabetic retinopathy
C. Allergy
D. Hyperthyroidism
5. Which technology/ies provide/s information on the posterior corneal curvature?

A. Pachymetry
B. Corneal tomography
C. Corneal topography
D. A & C
6. Panelists use the following top two criteria for evaluating keratoconus most frequently: _____.

A. Abnormal posterior curvature and abnormal corneal thickness
B. Clinically inflammatory corneal thinning and abnormal posterior distribution
C. Abnormal topography and abnormal corneal thickness and distribution
D. None of the above
7. _____ can accelerate the progression of keratoconus.

A. Hypertrophic cardiomyopathy
B. Pregnancy
C. Menopause
D. A & C
8. On corneal tomography, _____ is considered a red flag for keratoconus.

A. Posterior elevation greater than 15 to 20 µm
B. Thinnest pachymetry less than 600 µm
C. Anterior elevation greater than 7 µm
D. B & C
9. In practices without advanced diagnostic technology, _____ can be a red flag for keratoconus in a young patient.

A. Progressive hyperopia
B. Inability to correct to VA 20/20
C. Dysphotopsia
D. None of the above
10. _____ helps assess a patient's future risk of keratoconus based on an underlying risk factor for the disease.

A. Genetic testing for keratoconus
B. Corneal topography
C. Wavefront aberrometry
D. Autorefraction
11. The 2020 Market Scope keratoconus analysis reported that _____ people worldwide have keratoconus.

A. 13 million
B. 33 million
C. 43 million
D. 63 million
12. Which finding would prompt panelists to order genetic testing to determine the risk of keratoconus?

A. Neovascularization
B. Family history of keratoconus
C. Progressive hyperopia
D. Keratometry values greater than 37.00 D
13. Which of the following may slow or stop progression of keratoconus?

A. Corneal crosslinking
B. Hybrid contact lenses
C. Scleral contact lenses
D. None of the above
14. The following is true about genetic testing for keratoconus: _____.

A. It does not require a large capital outlay
B. It indicates the progression rate of keratoconus
C. It tests 55 genes
D. It indicates the severity of keratoconus
15. All panelists believe _____ is the most accurate diagnostic tool to detect keratoconus prior to loss of visual function.

A. Corneal biomechanics tests
B. Optical coherence tomography
C. Corneal topography
D. Corneal tomography
16. All panelists recommended _____ for ALL corneal refractive surgery candidates to help identify keratoconus suspects.

A. Corneal tomography
B. Corneal topography
C. Pachymetry
D. Wavefront aberrometry

ACTIVITY EVALUATION

Your responses to the questions below will help us evaluate this CME/CE activity. They will provide us with evidence that improvements were made in patient care as a result of this activity.

Rate your knowledge/skill level prior to participating in this course: 5 = High, 1 = Low _____

Rate your knowledge/skill level after participating in this course: 5 = High, 1 = Low _____

This activity improved my competence in managing patients with this disease/condition/symptom ____ Yes ____ No

Probability of changing practice behavior based on this activity: ____ Yes ____ No ____No change needed

If you plan to change your practice behavior, what type of changes do you plan to implement? (check all that apply)

- ☐ Change in pharmaceutical therapy
- ☐ Change in diagnostic testing
- ☐ Change in current practice for referral
- ☐ My practice has been reinforced
- ☐ Change in nonpharmaceutical therapy
- ☐ Choice of treatment/management approach
- ☐ Change in differential diagnosis
- ☐ I do not plan to implement any new changes in practice

Please identify any barriers to change (check all that apply):

- ☐ Cost
- ☐ Lack of consensus or professional guidelines
- ☐ Lack of administrative support
- ☐ Lack of experience
- ☐ Lack of time to assess/counsel patients
- ☐ Lack of opportunity (patients)
- ☐ Reimbursement/insurance issues
- ☐ Lack of resources (equipment)
- ☐ Patient compliance issues
- ☐ No barriers
- ☐ Other. Please specify: _____

The design of the program was effective for the content conveyed.	☐ Yes ☐ No	The faculty was effective.	☐ Yes ☐ No
The content supported the identified learning objectives.	☐ Yes ☐ No	You were satisfied overall with the activity.	☐ Yes ☐ No
The content was free of commercial bias.	☐ Yes ☐ No	Would you recommend this program to your colleagues?	☐ Yes ☐ No
The content was relative to your practice.	☐ Yes ☐ No		

Please check the Core Competencies (as defined by the Accreditation Council for Graduate Medical Education) that were enhanced through your participation in this activity:

- ☐ Patient Care
- ☐ Practice-Based Learning and Improvement
- ☐ Professionalism
- ☐ Medical Knowledge
- ☐ Interpersonal and Communication Skills
- ☐ System-Based Practice

Additional comments: _____

☐ I certify that I have participated in this entire activity.

This information will help evaluate this CME/CE activity; may we contact you by email in 3 months to see if you have made changes to your practice based on this activity? If so, please provide your email address _____

