

Prevailing practice patterns in keratoconus among Indian ophthalmologists

Rashmi Deshmukh¹, Alok Kumar Shrivastava^{1,2}, Pravin Krishna Vaddavalli^{1,3}

Objective: The past few years have seen a rapid advancement in the management of keratoconus (KC). However, there is no prescribed standard of care for the management of KC. This study evaluated the prevailing practice patterns among Indian ophthalmologists in the diagnosis and treatment of KC via an online survey. **Methods:** This was a survey-based cross-sectional study in which a questionnaire (Supplement 1) was created. Questions pertaining to the practicing experience, setting of practice, and training background were asked in addition to the investigations done and decision making in KC management. Responses were collected via Survey Monkey (Survey Monkey, Palo Alto, California, USA) and statistical analysis performed using R software (4.1.3). **Results:** The survey was answered by 273 ophthalmologists. Pentacam was the most used topographer (195 users), followed by Orbscan (41 users), Sirius (34 users), and Galilei (3 users). The lowest limit of pachymetry for performing collagen crosslinking (CXL) was 400 μ for most practitioners. More than half the respondents (50.55%) did not perform photorefractive keratectomy (PRK) or intracorneal ring segment (ICRS) implantation in a suitable patient. Accelerated 10-minute protocol (9 mW/cm² for 10 minutes) was the most commonly (54.21%) used for CXL, followed by Dresden protocol (3 mW/cm² for 30 minutes) (36.63%). When a patient was unsuitable for CXL, 55.31% surgeons advise contact lens (CL) trial, 35.16% surgeons advise keratoplasty, 26.74% surgeons perform stromal augmentation, and 7.69% surgeons advise spectacle correction. Corneal scar was the most common indication (49.45%) for performing keratoplasty. **Conclusion:** Topography remains the most used diagnostic modality for initial diagnosis. Optical coherence tomography and epithelial mapping are increasingly being used for early diagnosis of KC. Not all ophthalmologists were comfortable performing ICRS or PRK. When patients are unsuitable for CXL, CL trial remains the most frequently advised option followed by keratoplasty.

Key words: Keratoconus, practice patterns, survey

Introduction

After the initial description of keratoconus (KC) more than 150 years ago,^[1] the understanding of the disease has evolved significantly. The past 30 years have seen rapid evolution in the diagnostics and management protocols used for keratoconus. The advent of refractive surgeries has called for a better understanding and earlier diagnosis of the disease to prevent iatrogenic corneal ectasia. Consequently, the trends in clinical presentation have changed with KC being diagnosed at a younger age and at an earlier stage in the course of the disease.^[2] Moreover, the past three decades have witnessed a rapid evolution in the management of this disease including diagnostic modalities as well as treatment protocols.^[2]

While Placido-based topographers^[3] were common in the 1990s, slit scanning topography and Scheimpflug-based systems are now being used to better assess the posterior surface of the cornea.^[4] Newer diagnostic modalities like corneal biomechanics^[5] and epithelial mapping^[6] have been introduced to diagnose preclinical cases. Similarly, advancements have

been seen in the treatment protocols of KC as well. Until the last decade of 20th century, spectacles or contact lenses were prescribed for mild-to-moderate KC and penetrating keratoplasty (PKP) was performed for advanced disease. However, with the introduction of collagen crosslinking (CXL) in the early years of the 21st century, it was now possible to arrest progressive KC at an earlier stage.^[7] Around the same time, deep anterior lamellar keratoplasty (DALK) was described as an alternative to PKP to reduce the risk of rejection by retaining the host endothelial layer and a comparable visual outcome.^[8] Although CXL is the mainstay to stabilize the disease, various methods such as intracorneal ring segments (ICRS) or photorefractive keratectomy (PRK) combined with CXL aid in achieving better spectacle-corrected visual acuity, particularly in contact lens (CL) intolerant patients.

With such rapid advancements in the available diagnostics and treatment modalities, it is important to understand the practice patterns prevailing among ophthalmologists. The practices followed are likely to be influenced by various factors

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¹Cataract and Refractive Services, LV Prasad Eye Institute, Hyderabad, Telangana, ²Sri Innovation and Research Foundation, Ghaziabad, Uttar Pradesh, ³Shantilal Sanghvi Eye Institute, Hyderabad, Telangana, India

Correspondence to: Dr. Rashmi Deshmukh, LV Prasad Eye Institute, Road Number 2, Banjara Hills, Hyderabad - 500 034, Telangana, India. E-mail: dr.rashmi9@gmail.com

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such as the setting of the ophthalmic practice, experience of the ophthalmologist, and the training they have received resulting in a wide variability of practices followed in the management of keratoconus. We aimed to look at the practicing trends among Indian ophthalmologists in their management protocols for KC. This study was conducted to understand the prevailing practice patterns among Indian ophthalmologists via an online survey.

Methods

This was a survey-based cross-sectional study to assess the prevailing practice patterns among Indian ophthalmologists. A 14-question validated survey questionnaire (Supplement 1) was created using online platform (Survey Monkey, Palo Alto, California, USA). Questions were designed to gather information from practitioners regarding the duration of practice, setting of their practice, whether they were comprehensive ophthalmologists or specialists in cornea, and the number of keratoconus patients seen in their practice. Furthermore, questions delved into the details of diagnostic

modalities used in keratoconus such as topography, aberrometry, optical coherence tomography (OCT), epithelial mapping, and corneal biomechanics. Treatment pattern was assessed by enquiring about CL practice, CXL methods used, and indications for keratoplasty. Some questions had options of multiple choices to be selected, whereas others were single-choice questions only.

An email link was sent to all ophthalmologists registered in the All-India Ophthalmological Society (AIOS) database. Responses were collected via Survey Monkey (Survey Monkey, Palo Alto, California, USA), and statistical analysis performed using R software version 4.1.3.

Results

The survey was answered by 273 ophthalmologists [Fig. 1]. Of these, 32.97% had been practicing ophthalmology for >15 years, 17.95% were practicing for 10-15 years, 29.67% were practicing for 5-10 years, and 19.41% were ophthalmologists with a practicing experience of less than 5 years. Majority of ophthalmologists practiced in institutes (36.26%) followed by solo private practitioners (30.04%), corporate hospitals (17.95%), and group practice (13.92%). There were 121 comprehensive ophthalmologists (44.32%), 113 fellowship trained cornea specialists (41.39%), and 46 comprehensive ophthalmologists with focus on cornea. Around 66% ophthalmologists had 1-5 new KC patients presenting to their clinic in a month, whereas only 2.56% ophthalmologists had >30 new KC patients per month. Around 16.48%, 11.72% and 7.02% practitioners reported getting 6-10, 11-20, and 21-30 new KC patients, respectively. The most common age group of patients was 10-20 years (56.78%), followed by 20-30 years (47.25%), <10 years (5.13%), and >30 years of age (1.47%).

Diagnostic investigations in keratoconus

Respondents were asked about the topographers routinely used in their practice. The options provided were Orbscan, Pentacam, Galilei, Sirius, and others. If the respondents chose "others," then they were asked to mention which topographer they were using. Pentacam was the most used topographer (195 users), followed by Orbscan (41 users), Sirius (34 users), and Galilei (3 users). The option of "others" was chosen by 22 respondents, of which four practitioners did not use any topographer at all. Table 1 shows the number of ophthalmologists grouped according to their experience and the topographer used. Pentacam was the most used device across all the groups. Proportion of practitioners using different types of topographers grouped into the type of setting of practice was also noted [Table 2]. All three users of Galilei were from institute practice. Pentacam was the most frequently used device across all the practice settings.

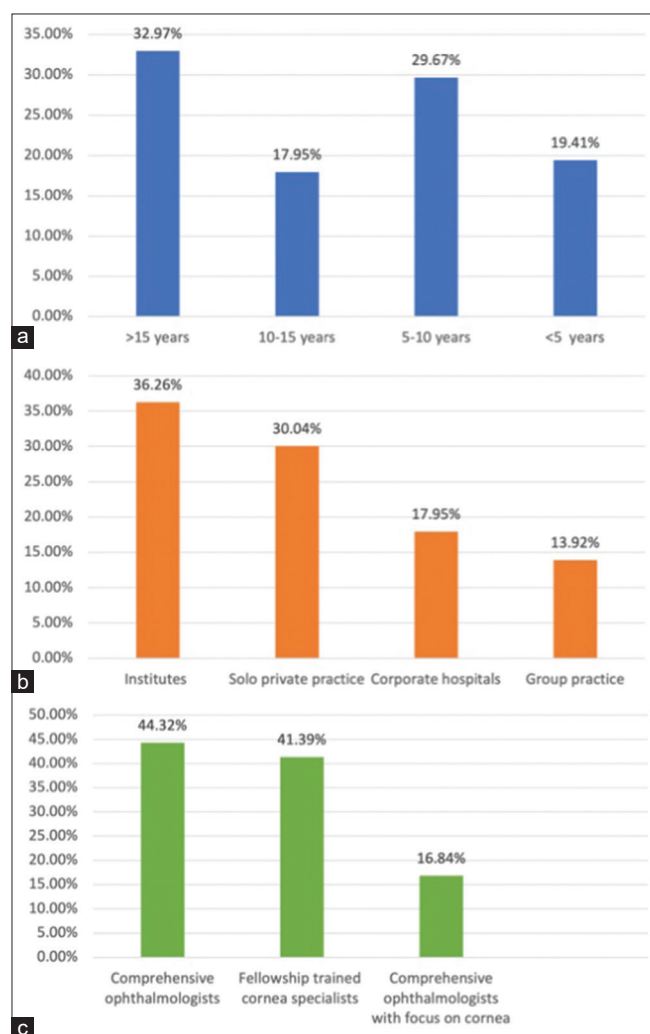


Figure 1: Graphs showing trends of (a) Practicing experience of ophthalmologists in the survey, (b) Practice setting of the ophthalmologists in the survey, (c) Training background of ophthalmologists in the survey

Table 1: Topographer used by ophthalmologists and the experience in practice

	<5 years	5-10 years	10-15 years	>15 years
Orbscan	15	7	7	12
Pentacam	36	58	37	65
Galilei	0	3	0	0
Sirius	2	13	5	13

When enquired about the investigations performed routinely in the first visit for a patient suspected of KC, 91.6% ophthalmologists got tomography performed, 38% advised corneal OCT, 26.4% advised epithelial mapping, aberrometry was advised by 19.6%, and corneal biomechanics was advised by 18.8%. This was a question where respondents could choose all applicable options. Interestingly, only 6 out of 273 respondents (2.19%) advise all the above-mentioned investigations done. Of these, three surgeons were fellowship-trained cornea specialists and 3 were comprehensive ophthalmologists.

Treatment advised

When a patient presents with eye rubbing, 84.62% stress the importance of avoiding eye rubbing and wait for progression, 8.42% responded that they prescribe topical anti-allergic medications in all patients with eye rubbing, topical lubricants were started by 5.86%, while 1.10% responded that they would perform CXL in all such cases.

Practice pattern in performing CXL

We also tried to evaluate the practice pattern in performing CXL. When taking a decision on performing CXL, age was the most important factor selected by 35.16% of the respondents, 9.16% responded that the presence of allergy would be the most important criterion for them, change in refraction was considered by 26.37%, increase in keratometry was the most important for 69.60%, and decrease in pachymetry was most important for 40.66%. Around 4% surgeons considered all the above factors for performing CXL. The lowest limit of pachymetry on topography for performing CXL was 450 μ for 10.99%, 400 μ for 50.18%, 370 μ for 25.27%, and 350 μ for 15.38%. Majority of the practitioners having lowest limit up to 350 μ had an experience of 5-10 years in practice. [Table 3] More than half the respondents (50.55%) did not perform photorefractive keratectomy (PRK) or intracorneal ring segment (ICRS) implantation combined with CXL in a suitable patient. PRK with CXL was performed by 24.18%, ICRS implantation was performed by 8.79% surgeons, and 17.95% surgeons were comfortable performing both PRK and ICRS with CXL. Looking at the trends between practicing experience with expertise in performing these procedures [Table 4] shows that majority of individuals performing ICRS or both ICRS and PRK had an experience of >15 years. Individuals comfortable doing PRK with CXL were almost equal in the groups of 5-10 years of experience and >15 years of experience. On analyzing the expertise in performing ICRS or PRK or both with training background [Table 5], majority of the practitioners comfortable in performing PRK or both ICRS and PRK were fellowship-trained cornea specialists.

Accelerated 10-minute protocol (9 mW/cm² for 10 minutes) was the most commonly (54.21%) used protocol for CXL, followed by conventional Dresden protocol (3 mW/cm² for 30 minutes) (36.63%), accelerated 5-minute protocol (18 mW/cm² for 5 minutes) (7.33%), and accelerated 3-minute protocol (30 mW/cm² for 3 minutes).

Practice pattern in advising Keratoplasty

When a patient was diagnosed with KC too advanced to be crosslinked, 55.31% surgeons advise contact lens (CL) trial, 35.16% surgeons advise keratoplasty, 26.74% surgeons

Table 2: Topographers used by ophthalmologists and the setting of practice

	Solo pvt	Group	Institute	Medical college	Corporate hospital
Orbscan	13	5	9	3	11
Pentacam	52	21	80	15	28
Galilei	0	0	3	0	0
Sirius	15	5	6	4	3

Table 3: Thinnest pachymetry used as cutoff for collagen crosslinking and the experience of practice

	<5 years	5-10 years	10-15 years	>15 years
450 microns	7	4	4	12
400 microns	29	38	22	47
370 microns	12	19	18	19
350 microns	5	20	5	12

Table 4: Practicing experience of ophthalmologists and the expertise in performing combined procedures with collagen crosslinking

	<5 years	5-10 years	10-15 years	>15 years
ICRS	6	4	2	10
Prk	8	24	9	23
Both	11	10	11	17
None	28	43	27	40

ICRS=Intracorneal ring segments, PRK=Photorefractive keratectomy

Table 5: Training background and the expertise in performing combined procedures with collagen crosslinking

	Comprehensive ophthalmologist	Fellowship trained cornea specialist	Comprehensive ophthalmologist focusing on cornea
ICRS	10	8	4
Prk	22	32	10
Both	16	26	7
None	69	47	22

ICRS=Intracorneal ring segments, PRK=Photorefractive keratectomy

perform stromal augmentation, and 7.69% surgeons advise spectacle correction. Among the different indications for performing keratoplasty, corneal scar was the most common indication (49.45%), followed by progressive keratoconus (28.94%), CL intolerance (16.48%), and poor spectacle-corrected visual acuity (5.13%).

Discussion

This online survey was conducted to understand the prevailing practices for investigating and managing a case of KC among Indian ophthalmologists. Majority of the practitioners had 1-5 new KC patients every month, whereas only 2.56% practitioners had >30 new patients with KC per month. The most common age group seen was 10-20 years of age. We tried to ascertain

whether the practicing patterns were influenced by the experience in years, setting of the practice, and the training background of the ophthalmologists to assess the influence of these factors on the diagnostic modalities used and the treatment protocols followed.

With the advancements in imaging modalities in the past 2-3 decades, several investigations have been introduced for earlier diagnosis of KC. Topography or tomography remains the first choice of investigation to ascertain the diagnosis in a suspected case.^[9] Corneal pachymetry and keratometry values also help in staging of the disease, and comparison of the maps over time is used to diagnose a progressive case requiring intervention.^[9] Various topographers based on different principles are available in the market. Orbscan uses slit-scanning and Placido-based technology to combine the assessment of anterior and posterior cornea along with the keratometry measurements to give a three-dimensional assessment.^[10] Pentacam uses a single rotating Scheimpflug camera, whereas Galilei uses dual rotating Scheimpflug camera in combination with Placido disk.^[11] Sirius topographer uses a combination of a single rotating Scheimpflug camera with a Placido disk.^[12] Studies have shown a difference in the repeatability of these devices in KC. A study comparing Orbscan, Pentacam, and Galilei showed Orbscan to be the least repeatable in comparison to the other devices.^[11] Another study comparing Sirius, Pentacam, and Galilei showed that Pentacam and Sirius were more repeatable than Galilei.^[13] It is known that due to the differences in the imaging principles and repeatability, the measurements of these devices cannot be used interchangeably.^[11] In our study, Pentacam was the most commonly used topographer, whereas Galilei was used by the least number of practitioners. Looking at the trend between topographer used and setting of practice showed that all the Galilei instruments were used by institute practitioners. Among the 273 respondents, four practitioners did not own a topographer at all.

While topographers remain widely used, they are influenced by poor ocular surface and have a longer acquisition time. Moreover, the repeatability of topographers is affected in the presence of haze in post-crosslinked corneas.^[4] Corneal OCT overcomes these issues giving a more reliable pachymetry map and has a shorter acquisition time.^[14] Apart from that, OCT is useful in determining the depth of corneal scars if any, and the depth of demarcation line in eyes that have undergone CXL.^[15] Epithelial thickness and corneal biomechanics have been recently introduced for diagnosis of early KC.^[16] Aberrometry aids in assessing visual performance and detecting subclinical KC.^[17] We asked individual practitioners about the investigations they would do when a patient presented with KC. Almost 92% ophthalmologists get topography done, more than 35% of ophthalmologists get anterior segment OCT done, more than a quarter responded that they get epithelial mapping done. Less than 1/5th of the practitioners advise corneal biomechanics and aberrometry in the first visit.

KC is known to be a progressive disease, and eye rubbing, atopy, and younger age at presentation are some of the common risk factors for progression.^[18] A recent study from Saudi Arabia revealed that almost 95% individuals with corneal ectasia were unaware of the relationship between eye rubbing and progression of KC.^[19] Patient education about avoiding habitual

eye rubbing is important to prevent progression and potentially avoid CXL.^[20] Anti-allergic medications to control itching achieve a similar effect in patients with atopy.^[21] Progressive disease needs CXL for stabilization. The decision to perform CXL in the first visit depends on patient's age, severity of KC, and presence of risk factors. We enquired about the treatment preferred by practitioners in a new patient presenting with history of eye rubbing and itching. More than 80% practitioners responded that they stress on a behavioral change and explain the importance of avoiding eye rubbing to avoid progression, whereas just over 1% ophthalmologists would perform CXL in the first visit without waiting for progression.

Progression of KC has been defined in different ways by various studies. Change in spherical equivalent, increase in keratometry values, and decrease in pachymetry have all been included as criteria for progression.^[22,23] Among the respondents of this survey, almost 70% practitioners used increase in keratometry values as the most important factor for determining progression. More than 40% practitioners used all the factors together for their decision.

Conventional Dresden protocol of CXL was described for corneas more than 450 μ thick on topography or having 400 μ of stromal thickness after epithelial removal, to prevent endothelial damage.^[7] Furthermore, developments have led to the development of different protocols for corneas less than 400 μ in thickness.^[24] Hafezi suggested that a minimum of 330 μ of stromal thickness is required for CXL using hypotonic riboflavin.^[25] Customized epithelial debridement for CXL has been described for corneas up to 350 μ . Around 11% respondents had the lowest limit of pachymetry as 450 μ , whereas more than 50% used 400 μ as their lowest limit for advising CXL. When assessed for the influence of years of experience, majority of the individuals performing CXL for up to 350 μ of corneal thickness were 5-10 years into practice. We postulate that practitioners who have been less than 5 years into practice might want to keep a higher limit of pachymetry to avoid complications and get better results in the early years if practice. Those with more than 10 years into practice might be following the protocols that have been introduced earlier keeping the limit of 400 μ . CXL can be combined with PRK or ICRS in suitable patients to improve spectacle-corrected visual acuity.^[26] However, these techniques need the expertise to get effective results. ICRS has a learning curve to select cases appropriately and manage complications such as false plane, corneal perforations, infective keratitis, migration, or extrusion of rings.^[27] Similarly, PRK with CXL would need training in planning the ablations for the best possible results.^[28] Around half of the respondents to this survey did not perform either of the procedures in a suitable case and would perform CXL alone. A quarter of the individuals were comfortable performing PRK with CXL. Less than 10% individuals performed ICRS, and around 17% individuals were comfortable performing both. Since both the procedures require training in patient selection and planning, we analyzed if there was a relationship with training background and years of practicing experience. Our analysis revealed that majority of the individuals performing both the procedures had >15 years of experience. Similarly, ICRS was performed by individuals with greater experience in practice, whereas PRK was performed equally by individuals 5-10 years into practice and those with >15 years of experience. Corneal fellowship training also affected the ability of

performing these procedures. Majority of the individuals who were comfortable performing both the procedures were fellowship-trained cornea specialists.

When performing CXL for corneas with more than 400µ of stromal thickness, several protocols have been described. Conventional Dresden protocol (3 mW/cm² for 30 minutes) is an epi-off protocol that has been considered the standard.^[29] However, it has the drawback of increased treatment duration resulting in intraoperative corneal dehydration and thinning. Accelerated protocols using 9 mW/cm², 18 mW/cm², and 30 mW/cm² for 10 minutes, 5 minutes, and 3 minutes, respectively, have been described as alternative protocols.^[30] A comparison of different protocols revealed that the Dresden protocol and the 10-minute accelerated protocol achieved better flattening of keratometry.^[31] Visual improvement was significant in all groups except the 3-minute accelerated protocol.^[31] The results of this survey revealed that majority of the practitioners perform 10-minute protocol followed by conventional Dresden protocol.

Traditionally, patients not suitable for CXL were given visual rehabilitation using spectacles or CL. When there is no visual improvement, keratoplasty in the form of DALK or PKP is performed. Recent advances have also seen improvements in CL designs for keratoconus^[32] and introduction of techniques for stromal augmentation using stromal lenticles^[33] or Bowman's layer transplant.^[34] Among the ophthalmologists who responded to this survey, around 55% practitioners give a CL trial for patients with a disease too advanced for CXL, whereas just over 25% practitioners perform stromal augmentation. There were more practitioners performing keratoplasties (35%) than stromal augmentation. Corneal scar was the most common indication for performing keratoplasty, followed by progressive disease. Around 16% individuals perform keratoplasty in patients unsuitable for CL.

Conclusion

The past few years have seen a rapid advancement in the field of diagnosis and management of KC. However, there is lack of consensus about the standard of care and our search of literature revealed no published standard advised for dealing with a patient of KC. While advances have been made in diagnosing the disease, different authors have defined progression using different criteria.^[22,23] There are several diagnostic modalities introduced other than topography, to aid in diagnosing early KC. There are several risk factors identified for progression, and CXL is needed in a progressive disease. Patients unsuitable for CXL are visually rehabilitated using spectacles or CL. Options of stromal augmentation surgeries have been introduced. DALK and PKP are performed for advanced cases with no visual improvement.

This survey was conducted to understand the prevailing practices in the management of KC. Topography remains the most commonly used diagnostic modality performed for initial diagnosis. Pentacam was more used than the other topographers available. Practitioners are also using OCT and epithelial mapping increasingly for early diagnosis of the disease. Once the disease was diagnosed, and risk factors identified, most practitioners believed in enforcing behavior change and prescribing anti-allergic medications and wait for progression before advising CXL. Increasing keratometry

was the criterion used by majority of the ophthalmologists for performing CXL, and a lower limit of 400µ of corneal thickness was preferred by more than half the respondents of this survey. Most commonly used protocols were the accelerated 10-minute protocol (9 mW/cm² for 10 minutes) followed by the conventional Dresden protocol (3 mW/cm² for 30 minutes). Not all ophthalmologists were comfortable performing ICRS or PRK. When patients are unsuitable for CXL, CL trial remains the most frequently advised option followed by keratoplasty. However, a significant number of ophthalmologists are also performing stromal augmentation. Corneal scar was the most common indication for performing keratoplasty. The study highlights the need to develop a preferred practice pattern protocol for the management of keratoconus.

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Conflicts of interest

There are no conflicts of interest.

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Supplement 1

1. For how many years have you been practicing ophthalmology?
 - ☐ <5 years
 - ☐ 5-10 years
 - ☐ 10-15 years
 - ☐ >15 years
2. What is the setting of your practice?
 - ☐ Solo practice
 - ☐ Medical college
 - ☐ Group practice
 - ☐ Corporate hospital
 - ☐ Institute
3. Are you:
 - ☐ A comprehensive ophthalmologist
 - ☐ A fellowship trained cornea specialist
 - ☐ A comprehensive ophthalmologist with focus on cornea
4. How many new KC patients do you see per month?
 - ☐ 1-5
 - ☐ 6-10
 - ☐ 11-20
 - ☐ 21-30
 - ☐ >30
5. What is the common age group of patients with KC you encounter?
 - ☐ <10 years
 - ☐ 10-20 years
 - ☐ 20-30 years
 - ☐ >30 years
6. Which topographer do you use in practice?
 - ☐ Orbscan
 - ☐ Pentacam
 - ☐ Galilei
 - ☐ Sirius
 - ☐ Other (please specify)

7. What are the investigations done routinely for a patient presenting for the first time with KC
 - ☐ Tomography
 - ☐ Aberrometry
 - ☐ Corneal biomechanics
 - ☐ AS OCT
 - ☐ Epithelial mapping

8. In patient with history of eye rubbing do you:
- ☐ Stress the importance of avoiding eye rubbing.
 - ☐ Prescribe topical anti-allergic medication to all.
 - ☐ Prescribe topical lubricants to all.
 - ☐ Perform CXL in all cases.
9. What is the most important criteria for you to consider crosslinking:
- ☐ Age
 - ☐ Allergy
 - ☐ Change of refraction
 - ☐ Increase in keratometry
 - ☐ Decrease in pachymetry
10. What would you do if a patient's cornea is too thin for CXL:
- ☐ Contact lenses.
 - ☐ Glasses
 - ☐ Keratoplasty
 - ☐ Stromal augmentation
11. In suitable patient, would you combine CXL with:
- ☐ ICRS
 - ☐ PRK
 - ☐ I am comfortable with performing both the above.
 - ☐ I don't perform either PRK or ICRS implantation.
12. Lower limit of thinnest pachymetry on topography for performing CXL:
- ☐ 450 microns
 - ☐ 400 microns
 - ☐ 370 microns
 - ☐ 350 microns
13. Your preferred protocol for performing CXL:
- ☐ 3mW/cm² for 30 minutes
 - ☐ 9mW/cm² for 10 minutes
 - ☐ 18mW/cm² for 5 minutes
 - ☐ 30mW/cm² for 3 minutes
14. Indications for performing or referring for a corneal transplant:
- ☐ Contact lens intolerance
 - ☐ Poor vision with glasses
 - ☐ Corneal scar
 - ☐ Progressive keratoconus