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REFRACTIVE SURGERY

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Achieving emmetropia is the main aim of keratorefractive and intraocular refractive procedures. The role of keratorefractive surgeries is limited in high refractive errors due to poor predictability, ectasia due to removal of excessive amount of corneal tissue, regression or refractive instability and decreased quality of vision due to corneal irregularity or scarring or induced aberrations. It has been shown that intraocular refractive procedure (phakic intraocular lens) has better safety, efficacy, predictability, and stability than laser in situ keratomileusis (LASIK) and in eyes with moderate to high myopia.

Several generations of both anterior and posterior PIOLs have been introduced in the past few years. Multiple studies from different parts of the world addressed the visual outcomes of both procedures, but a direct comparison in the same group of population has not been done. The purpose of this assessment was to review and compare the visual outcomes, efficacy and safety of posterior chamber implantable collamer lenses (Visian, STAAR Surgical Company, Monrovia, CA, USA) and iris-fixated phakic intra ocular lenses (Verisyse, Ophtec, Boca Raton, FL, USA), which are currently approved by the FDA.

MATERIALS AND METHODS

The study was approved by the Institutional Review Board of L V Prasad Eye Institute, Hyderabad, India, and was conducted in strict adherence to the tenets of the Declaration of Helsinki. Retrospective analysis of patients with myopia with ICL implantation between June 2008 and June 2010. Forty one eyes of 35 patients with iris-fixated phakic intra ocular lenses implantation (group 1, G-1) and 32 eyes of 23 patients with implantable collamer lenses implantation (group 1, G-2) for myopia.

Pre-operative evaluation included systemic and ocular history, refractive stability, uncorrected distant visual acuity (UCVA) and best spectacle corrected distant visual acuity (BCVA), manifest refraction, slit-lamp biomicroscopy, endothelial cell count (Confoscan III-Nidek Technologies, Vigonza, Italy), axial length measurement (IOL master v3.01, Carl Zeiss Meditec), topographic keratometry (off from soft contact lenses for 2 weeks and from rigid gas permeable lenses for 4 weeks), central corneal thickness measurement, anterior chamber depth of at least 3.0 mm from endothelium, horizontal white-white corneal diameter (Orbscan IIz; Bausch & Lomb, Rochester, New York, USA), intra ocular pressure by Goldmann applanation tonometry and fundus evaluation by indirect ophthalmoscopy.
**Posterior chamber ICL (Visian)**

The pupil was dilated with mydriatic drops and the procedure was performed under general anesthesia. A 3.2-mm temporal clear corneal incision and 2 paracentesis were created. The anterior chamber was filled with sodium hyaluronidate 1.4% (Healon GV). The ICL was then injected using an injector cartridge (STAAR Surgical), anterior and parallel to the iris plane, and allowed to unfold slowly. Each corner of the footplates was gently tucked beneath the iris. If necessary, adjustment of the ICL was accomplished by a gentle movement touching the ICL at the junction of the haptic and optic. Healon GV was completely replaced by balanced salt solution and intraocular miotic (0.13 mg/ml pilocarpine in BSS) was used to decrease pupil size.

**Iris-fixated PIOL (Verisyse)**

The pupil is constricted with miotic drops. Two paracenteses are created and the anterior chamber is filled with Healon GV. A scleral tunnel is made, usually in the steepest corneal meridian. The PIOL is inserted and rotated into a horizontal position. A fold of the peripheral iris is enclavated by pincher like lens haptics. A peripheral surgical iridotomy is performed. The incision is closed with an appropriate suture and the viscoelastic is removed. Follow-up examinations were scheduled at 1 day, 1 week, 1 month, 3 months, 6 months, and 1 year after surgery. Each procedure safety index and efficacy index were calculated as follows: safety index=mean postoperative UCVA/mean preoperative BCVA, and efficacy index=mean postoperative UCVA/mean preoperative BCVA

**RESULTS**

Pre-operative uncorrected and best corrected visual acuity (UCVA, BCVA), spherical equivalent (SE) and endothelial cell density (ECD) were comparable between the two groups (p>0.05). Mean logMAR UCVA, BCVA, SE in G-1 and G-2 at 1 month were 0.18 ± 0.14, 0.15 ± 0.15 (p=0.17), 0.05 ± 0.07, 0.05 ± 0.07 (p=0.78), -0.19 ± 0.64, -0.33 ± 0.70 (p=0.51), at 3 months 0.18 ± 0.16, 0.19 ± 0.17 (p=0.97), 0.06 ± 0.08, 0.08 ± 0.10 (p=0.64), -0.14 ± 0.67, -0.38 ± 0.41 (p=0.06), and at 12 months were 0.14 ± 0.13, 0.22 ± 0.23 (p=0.51), 0.07 ± 0.08, 0.07 ± 0.12 (p=0.37), -0.14 ± 0.57, -0.21 ± 0.26 (p=0.09) respectively. There was no statistical significant difference in the ECD either at 1 month (p=0.18), at 3 months (p=0.11) and at 12 months (p=0.31) between the two groups. Mean safety index was 0.22 ± 0.33 and 0.22 ± 0.45 (p=0.66) and efficacy index was 0.44 ± 0.52 and 0.90 ± 1.14 (p=0.19) at 12 months for G-1 and G-2 respectively.

Myopic patients with iris-fixated phakic intra ocular lenses implantation and implantable collamer lenses showed equal and comparable safety, efficacy and clinical outcomes.
Evaluation of Implantable Collamer Lens (ICL) Vaulting (VT), its Co-relation to Anterior Chamber Depth (ACD) and White to White (WTW) Measurements

Dr. Rohit Bang, Dr. Manasi JADHAV, Dr. Girish Shiva RAO

To study the co-relation between anterior chamber depth, white to white measurement and vaulting of implantable collamer lens.

MATERIALS AND METHODS

114 eyes of 68 patients were retrospectively analyzed. Pre-operative data of ACD and W-W and post-operative vaulting at 1 and 6 months was retrieved. ACD was measured on Pentacam and W-W measurement was taken under microscope in supine position with digital and vernier calipers. All patients were followed on post-op day 1, 1 week, 1 month, 6 months and then yearly. Vaulting of ICL was measured on Pentacam at 1 month and 6 months.

RESULTS

<table>
<thead>
<tr>
<th>Table 1: No of eyes and ACD and W-W range</th>
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<tbody>
<tr>
<td>ACD range (mm)</td>
</tr>
<tr>
<td>No of eyes</td>
</tr>
<tr>
<td>W-W range (mm)</td>
</tr>
<tr>
<td>No of eyes</td>
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</table>

<table>
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<tr>
<th>Table 2: Vaulting range</th>
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</thead>
<tbody>
<tr>
<td>Vaulting (microns)</td>
</tr>
<tr>
<td>No of eyes</td>
</tr>
</tbody>
</table>

Graph showing relation between ACD and W-W ratio and Vaulting

High ACD/W-W ratio gave higher vaulting.

Pentacam image showing vaulting
Ideal vaulting considered to be 300–900 microns was seen in eye with ACD/W-W ratio in range 0.25-0.35.

None of our patients developed any complications in 1 year.

**DISCUSSION**

- The plate–haptic design with central convex/concave optical zone incorporates a forward vault to lift lens away from anterior lens capsule
- The optic diameter and overall diameter of ICL is determined by power of the lens, W-W and ACD measurements 2,3,4.

In conclusion
- ICL implantation is a surgically less demanding procedure
- Accurate pre-op W-W and ACD measurements aid in selecting the correct lens to achieve ideal vaulting and desired visual outcome
- In our study we found that an ACD/W-W ratio in the range of 0.25-0.35 helps in achieving the ideal vault

**REFERENCES**


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**Microwave Thermoplasty – A Newer Therapeutic Treatment Modality for Keratoconus**

Dr. Kareeshma Wadia, Dr. Rohit Shetty, Dr. Sharon Dsouza

**Corneal collagen crosslinking (CXL) was introduced more than 10 years ago, with the first treatment performed in Dresden, Germany. In most cases, keratoconus progression either stopped or slowed after CXL treatment, but only occasionally did corneal topography and refractive outcomes such as UCVA, BCVA, and refraction improve. When there were improvements in corneal shape, they were typically modest. Using a procedure to add to the refractive outcome apart from just halting the progression of the condition,**
would probably yield a better result. We attempted to do so using the Keraflex KXS (Avedro, Inc., Waltham, Massachusetts), a microwave pulse treatment delivered to the cornea to improve its shape. By itself, CXL essentially freezes the cornea into a nonideal shape. Hence came the advent of the topography-guided ablation, treatment to improve the shape of the cornea. However, the cornea is already pressed for the availability of tissue, hence ablation may not be possible for all cases. Thermal energy can also be used to flatten the cornea before CXL treatment.

MATERIALS AND METHODS

50 eyes of patients with keratoconus were included in the study. The preoperative evaluation included uncorrected visual acuity, refraction and best corrected visual acuity, corneal topography using the Pentacam, Oculus Inc., and corneal biomechanics using CorVis ST, Oculus, Inc. Patients who had a central cone on the posterior elevation map of the Pentacam scan were included in the study and minimum pachymetry of 400 microns in the 3-4mm zone was the pre requisite. A central cone was defined as “the highest point of elevation lying within the 3mm zone or >50% of the cone falling into the 3mm zone.

The procedure was done under all aseptic precautions. The centre of the cornea was first marked and the suction ring of the Keraflex Vedera system placed at the limbus. Once the vacuum was engaged, the microwave thermal pulse was applied. Energy is applied using a dielectrically shielded microwave emitter which non-invasively contacts the epithelial surface. A single pulse raises the temperature of the 4.0mm ring of corneal stroma to approximately 65°C. The collagen shrinks and forms a toroidal lesion in the upper 150 microns of the stroma below Bowman’s membrane. The loose epithelium was removed using a Wecksel’s sponge and bandage contact lens was placed. The epithelium usually healed by 1-2 days, after which the bandage contact lens was removed.

Post procedure the patient was put on topical Prednisolone acetate eye drops 1%, Moxifloxacin eye drops 0.3% and lubricating eye drops. Post operative assessment included detailed slit lamp examination, Corneal topography, Anterior segment OCT and slit lamp photography. The corneal topography was repeated on the first post operative day after removal of the bandage contact lens. Timing of the cross linking was based on the biomechanical response of the cornea. A biomechanically strong cornea will withstand the effect of the thermal pulse and may not show much flattening, in which case one would not be expecting it to rebound much either, vice versa for the biomechanically weak corneas. The timing of the cross linking was based on the amount of flattening of the mean Keratometry value as follows: Flattening < 15 Diopeters- cross link on the same day, flattening 15-20D, cross link after 24 hours, flattening >20 D, cross link after 48 hours. At the time of cross linking,
the area of epithelium over the Keraflex ring was left intact. Epithelium within the 4mm ring of the Keraflex was removed and from 5-8 mm band was removed. Accelerated cross linking using 20minute soak time and 30mW/cm2 for 3minutes using the KXL, Avedro was done. Again, a bandage contact lens was placed until the epithelium healed, drops were to be continued as before.

Complete post operative assessment was repeated at 1 week, 1 month and 3 months after the procedure.

RESULTS
Mean preoperative K was 52.61 D. There was an initial drop in K values to 36.97 D on postoperative day 1, which showed a rebound to 40.98 D in the 1st 48 hours, at which point cross linking was performed. The post operative mean K at 1 month was 48.8 D, which stabilized to 48.03 D at 3 months. 5 eyes (10%) had early post operative anterior chamber inflammation, which was managed conservatively. Mean preoperative UCVA log MAR improved from 1.077 +/- 0.373 to 0.614 +/- 0.266 (p<0.001) at 1 month, and further to 0.565 +/- 0.236 (p<0.001) at 3 months. Only 9 patients had a follow up of upto 6 months. Their mean UCVA log MAR was 0.8, BCVA 0.314, mean keratometry 53.1 D at 6 months.

DISCUSSION
This is a new procedure for treatment of keratoconus, which reshaped the cornea without removing any tissue and preserving biomechanical integrity. By combining the procedure with modified ACXL, there is a marked improvement in the stability of the cornea. The keratometry values tend to increase at 3 months but have not yet reached pre operative values.

Limitations
The sample size and follow up period are too small to generalize the results of the procedure.

In conclusion at 3 months most patients of Keraflex did well, however, 9 eyes showed regression at the end of 6 months. Whether these values remain stable at 6 months or further regress has yet to be seen. At 3 months also, though the values of keratometry were below pre operative values, they had a tendency towards regression. A complete follow up for all the patients is required. Certain patients maybe predisposed to an anterior chamber reaction after the procedure. Ruling out any underlying causes like collagen vascular disorders, skin disorders like psoriasis, pre existing fever, etc. is essential before the procedure. Since the follow up is relatively short, regression cannot be ruled out, and long term follow up would be required to assess efficacy of the procedure. Regressed cases may require another procedure to stabilize the cornea.
Safety and Efficacy of a New Technique of Refractive Surgery: Femtosecond Lenticule Extraction Used for the Correction of Myopia: 3-Month Results

Dr. Somasheila Murthy, Dr. Rathi Varsha Madanlal, Dr. Swapnil Bhalekar

Use of femtosecond laser in LASIK limited to cut the flap, the effective refractive correction was further performed with the 193nm excimer laser. At present, 2 lasers are therefore necessary to complete the LASIK procedure.

The most recent advance goes beyond the flap’s creation with a curved ocular interface to therapeutic techniques that use the femtosecond laser for an all-in-one refractive procedure called FLEx (Femtosecond lenticule extraction). Instead of the excimer laser’s being used for the “refractive step,” the femtosecond laser creates a lenticule of corneal tissue for removal to cause the refractive change.

First clinical results with laser-induced extraction of a refractive lenticule were reported in 5 blind or amblyopic eyes 1 and 2 highly myopic eyes some years ago. Unfortunately, these first studies lacked a sufficient number of eyes and a detailed analysis of the achieved refractive data. Recently, Sekundo et. al.² and Blum et. al.¹ reported results of femtosecond lenticule extraction to treat myopia using a femtosecond laser without the need for excimer laser ablation.

The present study aims to assess results of a femtosecond lenticule extraction or FLEx procedure in patients having myopia and myopic astigmatism.

**MATERIALS AND METHODS**

Prospective interventional case series comprised of 22 eyes of 11 patients with stable myopia upto 10 D, minimum corneal thickness of 500µm and regular corneal topography pattern.

Ocular and systemic history, uncorrected distance visual acuity (UDVA), corrected visual acuity (CDVA) with current spectacles, history of stability of refraction, and objective and subjective refractions, slit lamp examination of cornea and retina, indirect ophthalmoscopy for peripheral retinal examination, intraocular pressure (IOP) (Goldmann applanation tonometry), corneal topography (Orbscan) and ocular wavefront aberrometry was performed for all the patients preoperatively and on 1 week, 1 month and 3 month postoperative visits.

The VisuMax femtosecond laser was used for performing FLEx procedure. The postoperative regimen consisted of preservative-free Moxifloxacin, Prednisolone acetate, and Carboxymethylcellulose (0.5%) lubricating drops.
each 4 times a day for 1 week. Subsequently, steroids were tapered and only the lubricating drops were used up to 3 months as needed.

Statistical analysis was performed using the data analysis features of Excel 2007 software (Microsoft Corp.).

RESULTS

22 eyes of 11 patients with myopia underwent FLEx (Femtosecond lenticule extraction). Mean age of the patients was 24.6 ± 5.58 years.

Visual Acuity

95% eyes achieved 20/25 or better UDVA and 100% eyes achieved 20/30 or better UDVA. Table 1 shows preoperative and 3 month postoperative mean manifest refraction for SE, sphere, and cylinder.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Preoperative Refraction</th>
<th>Postoperative Refraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Spherical</td>
<td>-5.51±1.57 (-2.5 to -7.50)</td>
<td>0.01±0.163 (-0.5 to 0.25)</td>
</tr>
<tr>
<td>Mean Cylinder</td>
<td>-0.538±0.40 (0 to -1.25)</td>
<td>-0.24±0.24 (0 to -0.50)</td>
</tr>
<tr>
<td>Mean SE</td>
<td>-5.78±1.61 (-2.5 to -7.88)</td>
<td>-0.10±0.21 (-0.50 to 0.25)</td>
</tr>
</tbody>
</table>

Refraction

100% of the eyes had postoperative Spherical Equivalent refraction within ±0.50D.

Predictability

The scatter plot in Figure 1 shows the regression line plot within the plot of the actual correction achieved versus the attempted refractive correction 3 months postoperatively.

Safety

18% of the eyes lost 1 line, 14% gained 1 line and 68% remained unchanged. None of the eyes lost 2 or more lines of visual acuity at 3 months.

Figure 1: Predictability: Scatterplot of the attempted SE refractive change plotted against the achieved SE refractive change at 3 months (n=22).
DISCUSSION
FLEx is a all in one femtosecond procedure during which no excimer laser is needed to complete the refractive correction. Preliminary results produced satisfactory results. In this limited number of eyes, FLE was seemed to be a gentle and safe procedure. Performing the FLEx procedure may be important for the surgeon before shifting over to SMILE (Small Incision Lenticule extraction). However, though it is a single stage procedure, has no added refractive advantage over the femtosecond LASIK. Study of larger numbers of patients with longer follow up is required to establish the stability over a long period.

REFERENCES

Prospective Study of Simultaneous Topo-guided Partial PRK followed by CXL for Keratoconus – 2 Year Results
Dr. Vardhaman Kankaria, Dr. Vasilios Diakonis, Dr. George Kymionis, Dr. Micheal Grenzelos

Keratoconus is a bilateral, non-inflammatory disorder characterized by progressive corneal thinning and bulging. The cornea assumes a conical shape due to its biomechanical instability, which leads to irregular astigmatism and decrease in visual acuity. Treatment of keratoconus consists of spectacles, contact lenses, intrastromal corneal ring segments and when these treatment options are no longer effective, lamellar or penetrating keratoplasty.

A relatively new surgical treatment used to strengthen the corneal tissue and stabilize the ectatic cornea in keratoconus is corneal collagen cross-linking (CXL) with riboflavin and ultraviolet-A (UVA). The goal of this approach is the stabilization of the cornea by augmenting the chemical bonds between the collagen fibrils.
Before CXL treatment, epithelium has to be removed in order to permit the penetration of riboflavin into the corneal stroma. Failure to achieve adequate stromal absorption of riboflavin may impair the efficacy of the crosslinking process.5

Excimer laser phototherapeutic keratectomy (PTK) is a well-known surgical technique that has successfully been used in the management of superficial corneal pathology, such as anterior corneal dystrophies, degenerations6 and the treatment of keratoconus nodules.7 In cases of transepithelial PTK (t-PTK) the excimer laser ablation is used in order to remove the epithelium and smooth the anterior irregular cornea.8,9

Recently, we reported significant visual and topographic improvement of keratoconus after epithelial removal with transepithelial phototherapeutic keratectomy (t-PTK) followed by CXL treatment. In another study, a combination of topography-guided custom ablation and CXL improved patients’ visual and topographic outcomes.

The aim of the current study was to compare the results of CXL with riboflavin and UVA irradiation for progressive keratoconus after epithelial removal with t-PTK and mechanical epithelial removal.

**MATERIALS AND METHODS**

**Design:** Prospective, comparative, interventional case series. Participants: Thirty-four patients (38 eyes) with progressive keratoconus were enrolled. All patients underwent uneventful CXL treatment. Sixteen patients (19 eyes) underwent epithelial removal using t-PTK (Group 1) and eighteen patients (19 eyes) underwent mechanical epithelial debridement using a rotating brush (Group 2) during CXL treatment. Visual and refractive outcomes were evaluated along with corneal confocal microscopy findings preoperatively and at 1, 3, 6 and 12 months postoperatively. Main Outcome Measures: Uncorrected distance visual acuity (UDVA), corrected distance visual acuity (CDVA), manifest refraction, keratometry readings.

**Clinical Evaluation**

Preoperative evaluation consisted of ocular and general health history assessment; autorefractometry and autokeratometry (Canon autorefractor; Canon USA Inc, Lake Success, NY); corneal topography (Technomed C-Scan, Baesweiler, Germany); uncorrected distance visual acuity (UDVA), distance corrected visual acuity (CDVA), manifest refraction; central corneal thickness using ultrasound corneal pachymetry (Corneo-Gage Plus; Sonogage, Cleveland, Ohio); and slit-lamp examination of the anterior and posterior segments of the eye.
Surgical technique

All procedures were performed under sterile conditions in our institute by the same surgeon (G.K.). After topical anaesthesia with proxymetacaine hydrochloride 0.5% eye drops (Alcaine, Alcon Labs), corneal epithelium was removed by t-PTK.

The Allegretto Wavelight excimer laser (Wavelight Technologies, Erlangen, Germany) was used for the procedure. The t-PTK ablation was performed in an 8.0 mm zone in an intended depth of 50μm. After t-PTK, riboflavin 0.1% solution was instilled on the centre of the cornea every 2-3 minutes, for approximately 30 minutes.

Penetration of the cornea and presence of riboflavin in the anterior chamber (riboflavin shielding) was monitored by slit-lamp examination. UVA irradiation was performed using a commercially available UVA optical system (UV-X illumination system version 1000, Zurich, Switzerland) with a light source consisting of an array of UV diodes (365 nm) with a potentiometer in series to allow regulation of voltage.

Before treatment, intended irradiance of 3.0 mW/cm² (5.4 J/cm² surface dose after 30 minutes) was calibrated using the UV-A light meter YK-34UV (Lutron Electronic) which is supplied with the UV-X device. Irradiance was performed for 30 minutes, corresponding to a dose of 5.4 J/cm². During treatment, riboflavin solution was applied every 3-5 minutes to saturate the cornea with riboflavin.

At the end of the procedure, a silicon-hydrogel bandage contact lens (Lotrafilcon B, Air Optix, Ciba Vision – 14.0mm diameter, 8.6 base curvature, Dk=140 barrers) was applied until full re-epithelialization.

Postoperative medication included diclofenac sodium 0.1% (Denaclof, Novartis) for 2 days as well as antibiotic/corticosteroid (tobramycin/dexamethasone) drops (Tobradex, Alcon Laboratories, Inc.) four times daily until the removal of the bandage contact lens.

After the removal of the contact lens, patients received corticosteroid drops (FML, fluorometholone 0.1%, Falcon Pharmaceuticals) tapering for the next 3 weeks. Patients were encouraged to use artificial tears at least six times per day for 3 months postoperatively.

RESULTS

In group 1, logarithm of minimal angle of resolution (LogMAR) mean UDVA and mean CDVA improved from 0.99±0.71 and 0.30±0.26 pre-operatively to 0.63±0.42 (p=0.02) and 0.19±0.18 (p=0.008) 12 months postoperatively, respectively.
In group 2, neither mean UDVA nor mean CDVA demonstrated a statistically significant improvement 12 months postoperatively (p>0.05).

In group 1, mean corneal astigmatism improved from -5.84±3.80D preoperatively to -4.31±2.90 D (p=0.015) at the last follow-up; while in group 2 there was no statistically significant difference at the same postoperative interval (p>0.05). No endothelial cell density alterations were observed throughout the follow-up period for both groups (p>0.05).

In conclusion, epithelial removal with t-PTK before CXL could improve patients’ visual outcomes. Longer follow-up and larger patient series are necessary in order to evaluate the outcomes of this combined procedure.

REFERENCES

Simultaneous Topography-Guided Surface Ablation with Collagen Cross-Linking for Keratoconus

Dr. Vishal Shah, Dr. Anand A Shroff, Dr. Ashok C Shroff

Keratoconus is an ectatic corneal disorder characterised by bilateral, asymmetric, non inflammatory, progressive forward protrusion and thinning of the cornea. It’s reported incidence is 1 in 2,000 in the general population. It is usually diagnosed at puberty and progression thereafter leads to severe visual deterioration due to irregular astigmatism and corneal scarring. Approximately 20% of the eyes progress to the extent that penetrating keratoplasty is indicated. Treatment options must improve 2 distinct parameters: optical inefficiency of the irregular cornea and corneal biomechanical instability. The optical inefficiency can be corrected with spectacles and contact lenses in the initial stages of the disease process. However with continued progression, several surgical options like intrastromal corneal ring segments, lamellar keratoplasty, or penetrating keratoplasty may be needed. Prior to the introduction of corneal collagen cross linking (CXL), there was no treatment capable of correcting the biomechanical instability. However, recently, surgeons have successfully used CXL to impede the progression of keratoconus.

This procedure builds the bonds between the collagen molecules and, therefore, increases corneal rigidity and stability. Visual performance in patients treated with CXL shows little or no improvement. Using CXL alone provided patients with stability; however, visual rehabilitation is very challenging especially in patients who are contact-lens intolerant. Dr. Kanellopoulos has performed topography-guided PRK in some of these patients, introducing the novel approach of a therapeutic partial topography guided PRK with satisfactory outcomes. This technique normalises the corneal surface by reducing irregular astigmatism and potentially the refractive error as well. Recently, a combined approach of simultaneous topography-guided surface ablation with CXL has been devised by Dr. Kanellopoulos. Patients experience improved visual outcomes in addition to stabilization of the ectatic process. Herein, we report the use of this combined approach for the treatment of keratoconus.

MATERIALS AND METHODS

This was a retrospective non randomised review of 16 eyes of 14 patients who underwent simultaneous topography guided surface ablation with collagen cross linking for progressive keratoconus at our hospital. Keratoconus was described as progressive when there was an increase in the cone apex.
keratometry of -0.75 diopters (D) or alteration of -0.75 D in the spherical equivalent refraction, in a period of at least 6 months. Those patients with a minimum of 3 months of follow up were included.

**Clinical Evaluation**

Preoperative evaluation included general and ocular health assessment; uncorrected visual acuity, refraction and best corrected visual acuity, corneal topography (Oculyzer, WaveLight), slit lamp examination of the anterior and posterior segments of the eye.

**Procedure**

The whole procedure was done in the LASIK operating room under topical anaesthesia. This technique is guided by the topography images which are fed into the software. This proprietary WaveLight software utilizes topographic data from the Oculyzer (WaveLight) and averages data from eight topographies. It enables the surgeon to adjust the desired postoperative corneal asphericity; the inclusion, or not, of tilt correction; and the adjustment of sphere, cylinder, axis and treatment zone. Our therapeutic goal was normalization of the cornea so that there is improvement in BSCVA and not emmetropia.

First a 7mm trephine was used to mark the area of the epithelium. Debridement was done in the marked area to remove the epithelium of the cornea. Then topography guided PRK was performed using the 500Hz Concerto excimer laser (Wavelight AG, Erlangen, Germany). In these cases, the only ablation is that of the topography-guided element, with refractions entered as zero, exclusion of tilt correction and 6.0 mm treatment zone. Immediately after the topo-guided PRK, a cellulose sponge dipped in chilled balanced salt solution was applied over the ablated cornea for 30 seconds followed by 0.02% Mitomycin C soaked cellulose sponge for 18 seconds. After thoroughly washing the Mitomycin C with chilled balanced salt solution, the riboflavin sodium phosphate ophthalmic solution (0.1%) was applied topically every 1 minute, for 30 mins to diffuse into the corneal stroma. We then irradiated the cornea with UV-A light of 370nm (range, 365-375nm) and an irradiance of 3mW/cm2 for 30 mins. At the end of this, a bandage contact lens was placed on the cornea. Patients were seen on the 1st postoperative day and then 3 days later when the bandage contact lens was removed after complete healing of the epithelium. Post-operatively, topical moxifloxacin eye drops 4 times/day, topical fluorometholone eye drops 4 times/day (tapered every 3 weeks) and lubricant eye drops were prescribed.

**Outcome Measures**

**Primary**

- Visual acuity – uncorrected and best corrected
- Change in keratometry values (individual as well as mean)
- Change in keratoconus indices

**Secondary**
- Corneal symmetry on topography
- Stabilisation of keratoconus
- Statistical analysis was done by the paired ‘t’ test using the SPSS software. An alpha level of p<0.05 was considered significant

**RESULTS**

**Demographic Data**
- 16 eyes/14 patients, 10 males/4 females, 2 – bilateral and 12 unilaterally underwent the procedure, age range – 18-41 years, follow up – 9-32 months; mean – 16.5 months, 12 eyes had finished > 1 year follow up on last visit.

**Visual Acuity**
- Improvement in uncorrected as well as BCVA was seen in 100 % eyes (range 1-3 Snellen lines)
- Non-significant trend towards improvement in manifest refraction spherical equivalent was also noted
- Trend in reduction of spherical equivalent
- Reduction in keratometric values
- Symmetry between the vertical hemimeridians
- Decrease in higher order aberrations

**Keratometric Indices**

<table>
<thead>
<tr>
<th></th>
<th>Pre-op</th>
<th>Post-op</th>
<th>“P” Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>K1</td>
<td>45.813</td>
<td>43.963</td>
<td>0.0042</td>
</tr>
<tr>
<td>K2</td>
<td>49.900</td>
<td>48.038</td>
<td>0.0287</td>
</tr>
<tr>
<td>MEAN K</td>
<td>47.750</td>
<td>45.888</td>
<td>0.0051</td>
</tr>
<tr>
<td>ISV</td>
<td>65.63</td>
<td>44.50</td>
<td>0.0018</td>
</tr>
<tr>
<td>IVA</td>
<td>0.6588</td>
<td>0.2950</td>
<td>0.0033</td>
</tr>
<tr>
<td>KI</td>
<td>1.1638</td>
<td>1.0700</td>
<td>0.0061</td>
</tr>
<tr>
<td>IHA</td>
<td>12.188</td>
<td>4.238</td>
<td>0.0370</td>
</tr>
<tr>
<td>IHD</td>
<td>0.02150</td>
<td>0.00663</td>
<td>0.0066</td>
</tr>
<tr>
<td>Rmin</td>
<td>6.2513</td>
<td>6.7200</td>
<td>0.0063</td>
</tr>
<tr>
<td>Rmin Back</td>
<td>4.6500</td>
<td>4.4712</td>
<td>0.0014</td>
</tr>
</tbody>
</table>

- Stabilisation of keratoconus achieved in all eyes
- No significant change in the intra ocular pressure
- No problems related to epithelial healing
• Minimal stromal edema and temporary subepithelial stromal haze was seen in the immediate postoperative period
• No cases of stromal scarring, demarcation line seen
• Corneal and lens transparency was maintained
• No adverse events were recorded in the study

**DISCUSSION**

Keratoconus is characterized by progressive thinning and ectasia which results in high and progressive irregular astigmatism. This leads to deterioration of the quality of vision and also the quality of life. As the disease begins in young adults, it affects the most productive years of life. For visual rehabilitation of keratoconic patients, photorefractive keratectomy has been used for several years. Alpins et al. reported a series of 32 eyes treated with photoastigmatic refractive keratectomy; patients were followed for up to 10 years with no evidence of keratoconic progression.  

The use of customized, topography-guided ablation to treat keratoconus has also been reported. Koller et al. treated 11 eyes with customized PRK and reported improvement in refractive astigmatism, topography, and quality of vision in all patients. In a study by Cennamo et al., 25 eyes treated with topography-guided PRK also had improved topography and visual outcomes. However, its main drawback is that it is a tissue removal technique. If done in isolation, the stromal thinning introduced by ablation may trigger further destabilisation of corneal biomechanics, progression of keratoconus, and astigmatism.  

With the advent of CXL, we now have a treatment modality in our armamentarium which stops the progression of keratoconus. CXL changes the intrinsic biomechanical properties of the cornea, causing an approximate increase in corneal rigidity by 70%. This increase in corneal strength has shown a revolutionary potential for retarding or eliminating the progression of keratoconus in numerous studies all over the world. However if CXL is done in isolation, optical inefficiency secondary to the irregular astigmatism persists. Visual rehabilitation is necessary after CXL. The modalities used currently include spectacles, rigid contact lenses, INTACS and phakic IOL’s. However, treatment with these modalities is highly challenging, unpredictable at times and unsatisfactory in most cases. Dr. Kanellopoulos has attempted topography-guided PRK, 12 months after corneal collagen cross linking for visual rehabilitation with satisfactory outcome. This 2 step approach, however, has 3 major limitations – removal of cross-linked corneal tissue, unpredictable corneal ablation rate and increased possibility of post-PRK haze.
By simultaneously combining the above two techniques, advantages of both of them can be achieved together. The main advantage of this technique is that the ablation does not interfere with the already crosslinked part of the cornea. On the contrary, crosslinking of the ablated stroma offers the advantage of depopulating keratocytes and reducing the possibility of haze formation.\(^9\) The ablation is capable of reshaping the corneal surface, and CXL then halts progression of the disorder.

In this article, we report our results of this combined procedure. There was a rapid and significant improvement in UCVA and BCVA (1-3 Snellen lines) in 100% eyes. A non significant trend in reduction of spherical equivalent as well as manifest refraction spherical equivalent was noted. We believe that apart from these changes in refraction, a reduction of keratometric values, symmetry between vertical hemimeridians and decrease in higher order aberrations would play a very important role in overall improvement in the quality of vision.

Topographic evaluation showed a marked improvement in irregularity. On statistical analysis of individual keratometric indices, a statistically significant difference was noted in individual as well as mean keratometry values (K1 – \(p=0.0042\), K2 – \(p=0.0287\), mean K – \(p=0.0051\)), index of surface variance (ISV – \(p=0.0018\)), index of vertical asymmetry (IVA – \(p=0.0033\)), keratoconus index (KI – \(p=0.0061\)), index of height asymmetry (IHA – \(p=0.037\)), index of height decentration (IHD – \(p=0.0066\)), minimum sagittal curvature (Rmin) of anterior (\(p=0.0063\)) and posterior (\(p=0.0014\)) corneal surfaces.

There were no signs of keratoconic progression noted in any of the eyes on last follow up. There were no significant changes in intraocular pressure post treatment. In our study, no problems related to epithelial healing were noted. Minimal stromal edema and temporary subepithelial stromal haze was seen in most eyes in the immediate post operative period which subsided with routine topical treatment. No cases of stromal scarring or visually significant subepithelial haze were seen. Demarcation line was seen on slit lamp examination in most eyes. No adverse events were reported in any patient.

The general changes produced by this combined treatment modality are flattening of the cone and improvement of the overall shape. This occurs because this treatment flattens the steepest area and steepens the flattest area. After the procedure, patients are easier to fit with contact lenses, which are also better tolerated than before. Increased functionality and delayed or eliminated need for PK are also benefits of this treatment. Indications for treatment will still change, and probably widen, as further studies shed more light on the subject. This combined approach has raised the bar even further with a treatment that appears safe and effective.
In conclusion the goal of simultaneous topography-guided PRK and CXL is to offer keratoconus patients corneal stability as well as functional vision. Reaching functional vision involves improving UCVA, BCVA, and corneal irregularity so that patients are less dependent on contact lenses to achieve better quality of vision. Topography-guided PRK is a predictable and effective technique to achieve remodeling of the corneal surface and rehabilitation of refractive impairment. CXL is capable of stabilizing the corrected cornea and inhibiting keratoconic progression. Simultaneous PRK followed by CXL seems to be a promising treatment capable of offering patients functional vision and halting progression of the disorder. Performing this technique with careful observation of safety aspects may offer patients with keratoconus the opportunity to gain functional vision, avoid complications of long-lasting contact lens use, and reduce the need for later PK. Larger, comparative studies establishing the safety and efficacy of this treatment and longer follow up is obviously necessary in order to further validate these results and potentially make this treatment available for ectatic corneal disorders.

Bilateral Comparison of Wavefront-Guided, Tissue-saving and Conventional Laser in situ Keratomileusis to Correct Low to Moderate Myopia

Dr. Yachana Prakash, Dr. Dandapani Ramamurthy, Dr. Chitra Ramamurthy

Objectives of the study is (i) to assess the visual outcome of wavefront-guided, tissue-saving and standard LASIK treatment in terms of uncorrected visual acuity and subjective refraction values separately for each procedure. (ii) To analyse contrast sensitivity in mesopic and scotopic conditions. (iii) To analyse the mean change in higher – order aberrations pre-operatively and post-operatively.

MATERIALS AND METHODS

Based on literature review, the following observations surface

- The association between Higher Order Aberrations and visual acuity is not yet fully understood.
- The wavefront error (root mean square) was an unlikely predictor of visual acuity.
• Direct comparisons of contra lateral eyes are relatively few and have not shown a statistically significant difference between wavefront guided and conventional treatment.

• HOAs can increase in eyes that have received wavefront guided LASIK treatment, particularly eyes with low amounts of pre-operative HOAs.

Study population
The patients who opted for LASIK treatment for correction of low to moderate myopia were enrolled into the study. Patients included both males and females, their age ranging from 18 years to 36 years.

Sample size and sample technique
Total number of patients = 53.

Patients were divided into three groups by randomization using the dice technique and the eyes of the patients were further randomized for the modality of treatment depending on the group assigned to the patient.

• Group 1 : WF guided treatment - standard LASIK treatment =15
• Group 2 : WF guided treatment - tissue saving treatment = 21
• Group 3 : Tissue saving treatment - standard LASIK treatment = 17

Data collection technique and tools
Data was collected by recording it from the case record sheets (patient particulars, vision, refraction values and contrast sensitivity values) and from the instruments directly (topography, aberrometry).

A proforma was used for recording the data on every follow-up visit. At the end of the follow-up an interview was done to fill the questionnaire to assess patient satisfaction.

Data analysis
SPSS software developed by the IBM Corporation was used for statistical analysis. Paired T-tests were done for comparative analysis of the data.

Salient findings
No statistically significant difference was found between the uncorrected visual acuity at the end of the follow-up in groups 1, 2 and 3 amongst the two treatment modalities used in the groups. The p–value was calculated to be 0.9841, 0.1635, 0.1669 in group 1, 2 and 3 respectively.

The contrast sensitivity in patients in group 1 was found to be better in the eyes that were treated with wave-front guided ablation compared to those treated with standard LASIK, the difference between the two was found to be statistically significant (p-value = 0.0182).
In the other two groups the difference between the contrast sensitivity of the eyes treated with different treatment modalities was not found to be statistically significant, though in group 2 better contrast sensitivity was seen in eyes that underwent wave-front guided ablation but this difference was not found to be quite statistically significant (p-value = 0.0609). In group 3 no statistically significant difference was found between the two treatment modalities (p-value = 0.6220).

The difference between the HORMS (higher order root mean square) values calculated for 5 mm pupil size for eyes that underwent a particular treatment was not statistically significant for all the three groups (p-value = 0.6624 for group 1, 0.5352 for group 2 and 0.3630 for group 3).

In group 1; 50% patients do not find any difference in vision between the two eyes, 21.43% patients feel the eye that underwent wave-front guided ablation has better quality of vision whereas 28.57% patients feel the same for the eye that underwent standard LASIK treatment. 47% patients in group 2 feel no difference in vision between the two eyes, 35% patients feel the vision in the eye that underwent wave-front guided ablation has better quality of vision than the eye that underwent tissue-saving treatment whereas 17.65% patients feel the opposite.

In group 3; 45.45% patients do not find any difference in the quality of vision in the two eyes, 45.45% patients prefer the vision in the eye treated with standard LASIK and 9% patients feel the quality of vision is better in the eye treated with tissue-saving algorithm.

In conclusion wavefront-guided ablation, tissue-saving procedure and standard LASIK are all comparable, with no statistically significant difference in terms of the following visual outcome parameters – post-operative uncorrected visual acuity, post-operative refraction values and higher-order aberrations when used to treat low to moderate myopia with low astigmatism.

Despite an overall reduction in contrast sensitivity, it is seen to be better in eyes that are treated with wave-front guided ablation when compared to the planoscan LASIK profile and the tissue-saving treatment algorithm.

**REFERENCES**

1. Similar visual outcomes can be obtained on using wavefront technology, tissue-saving treatment and conventional LASIK in patients with moderate myopia with low astigmatism.

2. For low contrast sensitivity wavefront guided treatment can be considered over conventional LASIK and tissue-saving treatment.

3. A larger, multi-centric study is required to further validate the findings of this study.
Corneal Changes following Collagen Cross Linking (CXL) and Simultaneous Topography Guided Photoablation with CXL for Keratoconus

Dr. Padmanabhan Prema, Dr. Bhaskar Srinivasan

Over the last decade, several clinical studies have confirmed the efficacy of the Collagen Cross Linking (CXL) procedure in arresting the progression of keratoconus. However, CXL alone does not address the problem of irregular astigmatism. Topography-guided customized ablation treatment (T-Cat) is an approach to improve the regularity of the corneal contour before CXL can stabilize it.

The aim of our study was to compare the outcomes of CXL alone and T-Cat with simultaneous CXL in patients with progressive keratoconus.

MATERIALS AND METHODS

This was a prospective, non-randomized study of 66 eyes of 50 patients who were diagnosed with progressive keratoconus. Of these, 40 eyes underwent CXL and 26 eyes underwent T-Cat + CXL.

Table 1: Changes in refractive, visual and topographic parameters following treatment in each group and statistical differences within and between each group.

<table>
<thead>
<tr>
<th>Mean change (Postop-Preop)</th>
<th>CXL Δ values (95% CI)</th>
<th>T-CAT+CXL Δ values (95% CI)</th>
<th>CXL vs TCAT Mean difference between Δ values (95% CI)</th>
<th>P' (CXL Vs T-CAT+CXL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retinoscopic cylinder (D)</td>
<td>1.02±3.16 (0.04-2.00)</td>
<td>2.87±3.22* (1.63-4.11)</td>
<td>-1.85±0.8 (-3.47, -0.23)</td>
<td>0.026</td>
</tr>
<tr>
<td>S.E (D)</td>
<td>0.44±2.16 (-0.23-1.11)</td>
<td>2.17±2.68 (1.14-3.2)</td>
<td>-1.73±0.63 (-2.99, -0.46)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>BSCVA (log MAR)</td>
<td>-0.06±0.23 (-0.13-0.01)</td>
<td>-0.09±0.18 (-0.16-0.02)</td>
<td>0.3±0.05 (-0.07, 0.13)</td>
<td>0.55</td>
</tr>
<tr>
<td>Steepest K (D)</td>
<td>-0.40±3.71 (-1.55-0.75)</td>
<td>-2.91±2.01* (-3.68 -2.14)</td>
<td>2.51±0.70 (1.10, 3.92)</td>
<td>0.005</td>
</tr>
<tr>
<td>Sag (D)</td>
<td>0.63±4.62 (-0.8-2.06)</td>
<td>-3.59±5.94* (-5.87 -1.31)</td>
<td>4.22±1.37 (1.44, 6.99)</td>
<td>0.004</td>
</tr>
<tr>
<td>Area (Sq.mm)</td>
<td>0.36±1.88 (-0.22-0.94)</td>
<td>2.04±4.84 (0.18-3.9)</td>
<td>-1.68±0.99 (-3.71, 0.35)</td>
<td>0.10</td>
</tr>
<tr>
<td>SRI</td>
<td>0.09±0.41 (-0.04-0.22)</td>
<td>-0.09±3.44 (-1.41-1.23)</td>
<td>0.18±0.67 (-1.12, 1.57)</td>
<td>0.79</td>
</tr>
<tr>
<td>SAI</td>
<td>0.16±1.56 (-0.32-0.64)</td>
<td>-0.72±1.18* (-1.17 -0.27)</td>
<td>0.88±0.33 (0.20, 1.56)</td>
<td>0.01</td>
</tr>
</tbody>
</table>
Criteria for inclusion and for choice of treatment

Eyes with documented progression of keratoconus and with a minimum pachymetry of 400µ were included in the study. Those amount them, with a minimum pachymetry of 450µ and with clear mires on the Topolyser were selected for the combined (T-Cat+CXL) treatment while the others underwent CXL alone.

All the patients underwent retinoscopy, visual acuity on the ETDRS chart, slit lamp examination, applanation tonometry, fundus examination, corneal topography (TMS IV), Corneal tomography (Pentacam). Corneal aberrations were calculated using the Vol CT software.

Outcome measures: The refractive, topographic, tomographic and aberrometric changes measured preoperatively and 3 and 6 months postoperatively were compared between both groups.

RESULTS

The changes in refraction, visual acuity, topography indices, pachymetry are shown in Table I and changes in Corneal aberrations are shown in Table II.

Our results clearly indicate that a combine T-Cat + CXL resulted in better refractive, topographic and aberrometric outcomes than CXL alone. However, long term follow-up is needed to confirm that the improvements seen with this combined treatment persist and result in a better quality of life for these patients.
Comparison of Automated and Partial Coherence Keratometry and Resulting Choice of Toric IOL

Dr. Jit Ale Magar, Dr. Garry Brian, Dr. Frank Cunningham

Cataract surgery is a refractive procedure. Patients and surgeons have high and increasing expectations about vision outcomes produced. To date, satisfaction has been achieved, in part, by improvements in cataract surgical techniques, intraocular lens (IOL) designs, biometry and formulas for IOL calculation.\(^1\)\(^2\) However, whilst pursuit of pseudophakic correction of refractive errors and some higher order aberrations (HOA) is now possible, clinically significant postoperative residual spherocylindrical errors (defocus >0.25 diopters [D] and astigmatism >0.50 D) are still commonly observed.\(^3\)\(^4\) This makes HOA correction with customized IOL designs practically redundant.

Corneal astigmatism is common in many populations. For example, in the United States, 15-20\% of cataractous eyes exhibit greater than 1.5 D;\(^5\) and, about 50\% of eyes have more than 1.0 D.\(^6\) Among the 40 to 64 years age group, prevalence of corneal astigmatism >0.50 D has been reported at over 49\%\(^7\). Refractive astigmatism in the phakic eye is the vector sum of that created by the cornea and crystalline lens. Cataract extraction removes the latter. It is replaced only if the IOL inserted is tilted or decentred.\(^8\) If no astigmatism is induced by the surgical incision, then the eye’s postoperative astigmatism is determined by that of the pre-surgical cornea. Although intraoperative techniques such as relaxing keratotomy\(^9\)\(^10\) and positioning of incision site\(^11\) have been used to mitigate astigmatism, toric IOL implantation is currently the procedure of choice. However, toric IOLs frequently produce a refractive outcome less than desired: at least 20\% of eyes exhibit greater than 1.0D postoperative astigmatism.\(^12\)\(^-\)\(^15\) Reasons for suboptimal outcomes include inaccurate determination of preoperative astigmatism, variation in the site and size of corneal incision, and initial misalignment and subsequent rotation of implant axis.\(^16\) Therefore, corneal astigmatism frequently confronts the cataract surgeon and its adequate correction remains a challenge.

Consistent correction of astigmatism at the time of cataract surgery requires accurate characterization of preoperative corneal astigmatism and an appropriate surgical incision. This is dependent on accurate reproducible keratometry.\(^17\)\(^-\)\(^21\) A variety of keratometers are available, ranging from conventional instruments that measure a small part of the corneal apex to more sophisticated devices precisely characterizing the topography of the entire cornea. However, many ophthalmic clinicians rely on (and prefer) a single conventional keratometer in everyday practice.\(^3\)\(^,\)\(^22\) Instrument choice may introduce a systematic error in keratometry determination. For example,
the partial coherence keratometer may produce steeper keratometry (K) readings.\textsuperscript{23,24} Any such discrepancy will be clinically important when vision rehabilitation is impacted by the resultant choice of toric IOL power and axis alignment.

Studies have compared corneal power and astigmatism obtained from various conventional and modern keratometers.\textsuperscript{17,19,20,23-27} However, to the authors’ knowledge, the effect of any observed inter-instrument keratometry difference on the choice of toric IOL has not been reported previously. This paper presents such a comparison of corneal astigmatism estimation and resultant selection of toric IOL for two conventional keratometers commonly used in surgical practice: an autokeratometer (KR-7100, Topcon Inc, Japan) and a partial coherence interferometry keratometer (IOLMaster 500, Carl Zeiss Meditec, Germany).

**MATERIALS AND METHODS**

Ethics approval was not required or sought for this retrospective study as it was independent of patient care and used de-identified data. The medical records of patients who had undergone routine cataract surgery at a single facility between July and December 2011 were randomly chosen for examination. Eyes with documented corneal pathology, a history of any corneal surgery (including refractive interventions and pterygium excision), recent contact lens wear, and variable keratometry readings due to unstable tear film were excluded. Of those remaining, 235 eyes were randomly selected and considered for analysis.

As was standard practice in this clinical facility at the time, corneal astigmatism for each eye was measured using an IOLMaster and a KR-7100. For each instrument, three consecutive readings were taken. Absolute corneal astigmatism power (plus cylinder form, in diopters) was calculated algebraically by subtracting the flat from the steep K reading. Axis of the plus cylinder was recorded.

Astigmatism is a vector quantity with magnitude (cylindrical power) and orientation (axis). Conventional clinical notation of the astigmatism must be transformed into a vector notation for a valid statistical manipulation.\textsuperscript{28-30} Therefore, corneal astigmatism estimates for each eye by each instrument were converted into vector forms consisting of a spherical (M) component and two astigmatic components: J0 (astigmatism power at 0 and 180 degrees, in diopters) and J45 (astigmatism power at 45 and 135 degrees, in diopters). These were calculated according to: \textsuperscript{28,31} where, S is the sphere (considered to be zero in this study), C is the absolute corneal astigmatism and \( \alpha \) is the axis of the astigmatism.
To determine any difference between the two instruments for estimation of corneal curvature and astigmatism, eyes were categorized as following. For corneal curvature, the “average K” (the mean of the eye’s steep and flat keratometry powers) was calculated for each eye with each instrument. Then each eye was categorized with respect to the mean “average K” across both instruments: high (>45.0 D); moderate (≤45.0 but ≥42.0 D); and, low (<42.0 D). For absolute corneal astigmatism, categorization was according to the mean astigmatism of the two instrument values: high (>2.5 D); moderate (≤2.5 but ≥1.0 D); and, no or low (<1.0 D). The difference in each astigmatic component (J0 and J45) was calculated for each group.

To determine the effect of keratometry difference on the choice of the toric IOL cylinder power, mean differences in vector components were transformed back to the conventional notation of cylinder power using the equation.

\[
C' = \text{vector component} \times \frac{t}{n}
\]

where; \(t\) is the distance from the corneal surface to the IOL Plane (here considered to be 5.4 mm); and, \(n\) is the refractive index of the aqueous (1.336). Most toric IOLs currently in the market are available in 0.5 D cylinder increments. Therefore, the CylIOL power was rounded to the nearest 0.5 D before comparison.

Data analysis used PASW/SPSS Statistics 18.0 (SPSS Inc, Chicago, IL, USA) and Analyse-it (Analyse-it Software Inc, Leeds, UK) Add-in software for Excel (Microsoft Corporation, Redmond, WA, USA). Comparisons of astigmatism across the total sample were made using the paired t-test. Agreement between the keratometers was tested using Bland-Altman analysis. P-value <0.05 was considered statistically significant. Spherical component was not considered for analysis.

**RESULTS**

Analysis of J0 and J45 components determined by the IOLMaster 500 and KR-7100 across the corneal curvature and astigmatism groups of eye examined is summarized in Table 1. A high correlation (\(p < 0.001\)) between the values for the two instruments can be observed for each astigmatic component in all groups (Figure 1).

A marginal statistical difference between the instruments occurred for J45 components of the moderate...
average K (\( p = 0.048 \)), no or low (\( p = 0.006 \)) and moderate (\( p = 0.032 \)) astigmatism groups (Table 1). The difference between the instruments for astigmatic components of all eyes was statistically significant: mean (± standard deviation) for J0 and J45 were -0.005 D (±0.195, \( p = 0.013 \)) and 0.028 D (±0.180, \( p = 0.012 \)), respectively.

Significant differences between the instruments (\( p < 0.05 \)) were observed in cylindrical power of the toric IOL in all corneal curvature and astigmatism groups of eyes, except for those with low average K (\( p = 0.366 \)) and high astigmatism (\( p = 0.194 \)) (Table 2). The mean (± standard deviation) cylinder power calculated from the IOL Master (1.251±0.992 D) for the entire sample of 235 eyes was statistically different (0.128±0.308 D; \( p < 0.001 \)) from that for the KR-7100 (1.123±0.961 D). However, there was high correlation (\( R^2 = 0.904 \)) for CyIIOL as determined by both instruments (\( p < 0.001 \)) for all eyes (Figure 2). The difference in anticipated toric IOL cylindrical power was poorly correlated with the mean corneal curvature (\( R^2 = 0.007 \)) (Figure 3A) and keratometric corneal astigmatism (\( R^2 = -0.004 \)) (Figure 3B).

Across all 235 eyes, compared with the KR-7100, the IOLMaster tended to over-estimate average K by 0.27±0.26 D. It also tended to over-estimate corneal astigmatism power (0.13±0.31 D) and the toric IOL cylinder power (0.11±0.18 D, Figure 4: Bias 0.06).

Good agreement between the two instruments was achieved where IOL cylindrical power was within ± 0.50 D
Power calculations. However, the IOLMaster has been used in non-toric IOL power calculations for average K19207. Various keratometers have been demonstrated by high accuracy and high repeatability. Power calculation: source of error in IOL length measurement. However, keratometry remains an important vision rehabilitation. Post-cataract surgery.

Consistently good post-cataract surgery vision rehabilitation requires accurate and reproducible keratometry. Techniques such as partial coherence interferometry and immersion ultrasound have been substantial improvements in axial length measurement. Keratometry remains an important source of error in IOL power calculation. Accuracy and high repeatability have been demonstrated by various keratometers for average K19207.

Table 1: Comparison of mean (± standard deviation) corneal astigmatism vector components (J0 and J45) and difference as measured by a partial coherence interferometry keratometer (IOLMaster 500) and an autokeratometer (Topcon KR-7100) for 235 eyes grouped according to mean keratometry and absolute corneal astigmatism power.

<table>
<thead>
<tr>
<th>Eyes with...</th>
<th>n</th>
<th>IOLMaster 500</th>
<th>KR-7100</th>
<th>Correlation R²</th>
<th>p-value</th>
<th>Difference</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>28</td>
<td>0.239 ± 0.732</td>
<td>0.190 ± 0.759</td>
<td>0.947</td>
<td>0.000</td>
<td>0.049 ± 0.244</td>
<td>0.301</td>
</tr>
<tr>
<td>Keratometry (&quot;average K&quot;)§</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate</td>
<td>138</td>
<td>-0.071 ± 0.476</td>
<td>-0.091 ± 0.418</td>
<td>0.947</td>
<td>0.000</td>
<td>0.020 ± 0.156</td>
<td>0.511</td>
</tr>
<tr>
<td>High</td>
<td>69</td>
<td>0.021 ± 0.417</td>
<td>-0.011 ± 0.375</td>
<td>0.897</td>
<td>0.000</td>
<td>-0.031 ± 0.185</td>
<td>0.048</td>
</tr>
<tr>
<td>Absolute corneal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Astigmatism power</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No or Low</td>
<td>131</td>
<td>0.038 ± 0.262</td>
<td>0.043 ± 0.192</td>
<td>0.809</td>
<td>0.000</td>
<td>-0.004 ± 0.155</td>
<td>0.735</td>
</tr>
<tr>
<td>Moderate</td>
<td>131</td>
<td>0.019 ± 0.235</td>
<td>-0.013 ± 0.187</td>
<td>0.833</td>
<td>0.000</td>
<td>0.032 ± 0.130</td>
<td>0.006</td>
</tr>
<tr>
<td>High</td>
<td>83</td>
<td>-0.002 ± 0.757</td>
<td>-0.006 ± 0.685</td>
<td>0.953</td>
<td>0.000</td>
<td>0.003 ± 0.233</td>
<td>0.891</td>
</tr>
</tbody>
</table>

Units=dioptre (D): * Fourier rectangular vector: corneal astigmatic component at 0 and 180 degrees; # Fourier rectangular vector: corneal astigmatic component at 45 and 135 degrees; § low (<42.0 D); moderate (≤45.0 but ≥42.0 D); high (>45.0 D); ¶ no or low (<1.0 D); moderate (≤2.5 but ≥1.0 D); high (>2.5 D)
found to over-estimate average K by 0.42 D when compared with a manual keratometer, and, among six-year olds, by 0.29 D when compared with a RK-F1 autokeratometer (Canon Inc, Tokyo, Japan). The current study agrees well with the latter, over-estimating average K by 0.27 D (± 0.26) against the Topcon KR-7100 autokeratometer. Depending on other surgical influences, this may have clinical import, given that approximately 0.25 D defocus may cause noticeable blur.

Few studies have examined instrument accuracy in estimating corneal astigmatism power. One investigation reported that the IOLMaster recorded approximately 0.10 D greater astigmatism than either manual or corneal topography methods. In another study, comparison was made with a RK-F1, again showing an over-estimation of approximately 0.10 D by the IOLMaster. However, these analyses used conventional astigmatism notation, making comparison with the current study less satisfactory. Even so, there is agreement. The difference in J0 (-0.01±0.20 D) and J45 (0.03±0.18 D) components of the corneal astigmatism as measured by the IOLMaster and KR-7100 in the current study is equivalent to 0.13 ± 0.61 D in conventional notation measured at the cornea.

This study uniquely considers the implications of varying estimation by two conventional keratometers.

### Table 2: Mean (± standard deviation) and differences in toric IOL cylinder power calculated from data from a partial coherence interferometry keratometer (IOLMaster 500) and an autokeratometer (Topcon KR-7100) for 235 eyes grouped according to mean keratometry and absolute corneal astigmatism power

<table>
<thead>
<tr>
<th>Eyes with...</th>
<th>n</th>
<th>IOLMaster 500</th>
<th>KR-7100</th>
<th>Correlation R²</th>
<th>p-value</th>
<th>Difference</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean keratometry</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>28</td>
<td>1.433 ± 1.122</td>
<td>1.371 ± 1.144</td>
<td>0.952</td>
<td>0.000</td>
<td>0.061 ± 0.352</td>
<td>0.366</td>
</tr>
<tr>
<td>Moderate</td>
<td>138</td>
<td>1.269 ± 0.992</td>
<td>1.134 ± 0.930</td>
<td>0.941</td>
<td>0.000</td>
<td>0.136 ± 0.329</td>
<td>0.000</td>
</tr>
<tr>
<td>High</td>
<td>69</td>
<td>1.351 ± 1.002</td>
<td>1.012 ± 0.931</td>
<td>0.024</td>
<td>0.842</td>
<td>0.339 ± 1.351</td>
<td>0.041</td>
</tr>
<tr>
<td>Absolute corneal astigmatism</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No or Low</td>
<td>131</td>
<td>0.643 ± 0.298</td>
<td>0.498 ± 0.214</td>
<td>0.464</td>
<td>0.000</td>
<td>0.145 ± 0.273</td>
<td>0.000</td>
</tr>
<tr>
<td>Moderate</td>
<td>83</td>
<td>1.521 ± 0.513</td>
<td>1.521 ± 0.513</td>
<td>0.872</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>High</td>
<td>21</td>
<td>3.572 ± 0.815</td>
<td>3.347 ± 0.775</td>
<td>0.135 ± 0.461</td>
<td>0.194</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
of corneal astigmatism on the cylindrical power of the toric IOL suggested for insertion during cataract surgery. Given that, approximately 0.50 D cylindrical power is sufficient to degrade visual acuity, the difference in resultant toric IOL cylinder power (0.11 ± 0.18 D) as determined by the IOLMaster and KR-7100 is unlikely to have significant clinical implication in most patients. However, the difference exceeded a clinically significant level in about 40% of eyes examined.

Poor correlations between the difference in calculated toric IOL cylindrical power and the mean corneal curvature and keratometric astigmatism were found (Figures 3A and 3B). This indicates concordance of the two instruments across all corneal curvatures and astigmatism. A limitation of the current study is that it did not investigate difference across the entire corneal surface. However, corneal curvature beyond 1.5mm radius from the apex is less important in determining toric IOL power.

In conclusion, this study shows that the IOLMaster and KR-7100 autokeratometer are generally concordant in measuring corneal astigmatism power. However, the resultant choice of toric IOL cylinder power will differ appreciably on occasions (40%). Therefore, in everyday clinical practice, a thorough analysis of biometry data, paying special attention to any difference in corneal astigmatism as measured by more than one instrument is recommended prior to selection of a toric IOL for implantation.

REFERENCES


