THE ROLE OF ORTHOKERATOLOGY IN REFRACTIVE CORRECTION AND AN ANALYSIS OF CHANGES IN CORNEAL TOPOGRAPHY FOLLOWING OVERNIGHT ORTHOKERATOLOGY

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CONTENTS

INTRODUCTION

Orthokeratology

The word ‘orthokeratology’ is derived from Greek roots and comes from ‘ortho’ meaning correct or proper and ‘keratology’ meaning having to do with the cornea. It thus means forming the cornea to a correct shape.[1] Orthokeratology may also be considered to literally mean “the study of straight corneas”.[2]

Orthokeratology is defined as the reduction, modification or elimination of refractive error by the programmed application of specially designed rigid gas permeable contact lenses.[3]

It flattens the central anterior portion of the cornea, thus compensating for the abnormally long eye, in order to reduce or correct myopia.

Historical background

Various methods of correcting myopia through manipulation of ocular structures or exercises have been reported during the last 300 years.[2]

The early Chinese applied small bags of sand to their eyelids overnight in an attempt to alter their refractive error.[2]

Various devices, such as the “cornea restorer,” were developed and used for applying pressure to the front of the globe in the 1860s.[4]

With the introduction of polymethyl methacrylate (PMMA) corneal contact lenses, eye care practitioners began to notice that many young myopic wearers of contact lenses seemed to have some improvement in their vision, a reduction in their myopic progression or both.[5,6,7,8] This phenomenon was first reported at the 1957 International Congress on Contact Lenses held in Chicago and numerous papers followed describing the corneal and refractive changes associated with wearing PMMA corneal contact lenses.[9]

In 1962, **George Jessen** became the first clinician to report on deliberate attempts to alter corneal curvature with PMMA contact lenses by means of his “orthofocus” techniques, which he later termed orthokeratology.[2]

The orthofocus technique utilized a plano power contact lens that was fitted flat enough to allow correction of the refractive error by the tear lens formed behind the contact lens. The overall diameter of the lens was adjusted to the minimum size that would maintain centration. These flat fitting lenses were extremely uncomfortable for high myopes.[2]

In 1976, **Kerns** proposed a definition that considered both the purpose and methods of orthokeratology as a "purposeful attempt to modify the corneal curvature to result in a reduction or elimination of a refractive anomaly by a programmed application of contact lenses".

Orthokeratology has been practised in the United States for over 30 years[10] but with controversial and mainly anecdotal results. Early techniques such as the May-Grant and Tabb methods[10] used a series of progressively flatter lenses with a total diameter of about 10mm and a back optic zone diameter (BOZD) of about 8.50mm. The results proved unpredictable and lens decentration frequently induced significant corneal distortion. The myopia reduction achieved (approximately 1.25D) was not as large as claimed.

Orthokeratology has evolved from the "**standard**" technique to the "**accelerated**" technique through the years.

The practice of "**standard orthokeratology**" involved fitting conventional rigid contact lenses as flat as possible while still maintaining acceptable lens position on the cornea. With this technique, the time taken to achieve refractive correction ranged anywhere between three to ten months with varied myopia reduction rates reported among individual patients during the treatment time. The method of fitting progressively flatter lenses also led to an increase in with-the-rule astigmatism due to high riding of the flat lenses causing inferior corneal steepening. This phenomenon gives credence to the theory that "corneal power can neither be created nor destroyed, it is simply redistributed."

Predicting the success of ortho-k using the early fitting methods was dependent on the initial shape of the cornea which was determined based on an inherently inaccurate corneal measurement system of keratometry. It was thought that the more spherical the cornea and the lower the eccentricity, the smaller the ortho-k effect. As a result, corneas that had steeper curves and higher eccentricities were believed to have a better chance of experiencing a reduced myopia.

Research studies on Standard Orthokeratology

The first controlled study of orthokeratology was conducted by Kerns in 1973.[11-17] It involved an experimental group consisting of 18 subjects (36 eyes) and a control group of 3 spectacle wearers (6 eyes) and 13 PMMA contact lens wearers (26 eyes) with a conventional alignment fitting. The experimental group wore lenses designed according to the method of Grant and May.[2] The study was conducted during a 1000 day period, after which the lenses were not worn for 60 days. The lens base curve-cornea relationship ranged from 1.50D steep to 2.75D flat. Among all subjects, 70% were fitted "flatter than K," 13% were "on K" and 8% were "steeper than K." changes in refractive error ranged from an increase in myopia of 0.75D to a decrease of 3.00D with an average reduction of myopia of 0.77D after 10months as measured by a spherical equivalent refraction. An additional reduction of 0.40D was achieved very slowly over the next 20months. Of the 36 eyes in the study group, 27% had no change, whereas an increase in with-the-rule astigmatism developed in 56%. When the lenses were discontinued, both corneal curvature and visual acuity regressed towards pre-fitting values.

The second controlled study was reported by Binder et al. in 1980.[18] 20 patients who were fitted with 0.75D to 2.50D "flatter than K" were compared with 16 patients fitted "on K" during a 40 month period. The study group was further divided into three response groups. The "no response" group consisted of five subjects with the highest initial mean refractive error (-3.95D). The "variable response" group of six subjects had the lowest initial amount of myopia (-1.98D). The "good response" group of nine subjects had a moderate amount of myopia initially (-2.03D). The mean changes in spherical equivalent refractive errors were none, 0.39D and 1.52D for each group, respectively. Most of the myopia reduction was achieved within the first three months, with the maximum change occurring at 9 months and only minimal additional changes at 18 months. These investigators concluded that there were no factors that could predict the outcome of the procedure.

Polse and colleagues published the third controlled (first randomized and masked) study in 1983.[19-22] Forty test subjects were fitted 0.30D “flatter than K” and 40 control subjects were fitted in alignment with conventional PMMA contact lenses. The subjects were then followed for 36months. 21 subjects were lost to follow up, leaving 31 treatment and 28 control subjects who completed the study. Although it was variable, the treatment group after 444 days showed an average reduction in myopia of 1.01D in comparison with 0.54D in the control group. The major changes occurred within the first 132 days of lens wear with little additional change occurring during the remaining 241 days of the study. Once the lenses were removed, the refractive error returned to within 25% of baseline after 95 days.

The last of these controlled studies was published by Coon in 1982 and 1984.[23,24] Coon selected the Tabb method to fit 24 subjects “steeper thean K” (0.25 to 0.75D) and followed them for 15 months. Spherical equivalent refractive error was reduced by nearly 1.00D in 5months. However, by the end of the study, the mean reduction in myopia was only 0.56D. Coon also reported that there was no significant increase in with-the-rule astigmatism.

From the aforementioned studies, the following conclusions are evident:

- Orthokeratology with PMMA contact lenses presents no greater risks to ocular health than the wearing of standard PMMA lenses.
- Although individual cases may vary, on average, only modest reductions in myopia of about 1.00D can be expected.
- Improvement in unaided visual acuity does not directly correlate with changes in corneal curvature or reduction in myopia
- Because the different fitting methods produced about the same amount of myopia reduction, factors other than the cornea-base curve relationship must be in play.
- Most of any myopic reduction will take place within the first 6 months of treatment, but additional changes may occur at or beyond 12 months.

- Induced with-the-rule astigmatism and corneal distortion may occur, especially when flatter lenses are fitted that may not center well.

- There are no patient characteristics or findings that will predict the outcome.

- Any improvement in refractive error is not permanent and requires the use of retainer lenses.

Based on the results of these studies, conventional orthokeratology fell into disfavor among most eye care practitioners and was declared a non viable option for myopia correction in ophthalmologic literature.[25-32] But continued refinements in the techniques of orthokeratology have enabled clinicians to deliver more controlled and predictable results.

Orthokeratology did not gain widespread acceptance in the initial years partly due to resistance from the scientific community because they maintained that altering the central cornea would not be safe. The fact that only keratometry was available to evaluate, demonstrate and monitor corneal topographic changes limited the use of ortho-k to a body of fitters who had ample anecdotal evidence, yet little scientific data.

A more scientific approach was conferred to orthokeratology[10] with the advent of:

- Reverse geometry lenses
- Corneal topography measurement so that changes in corneal curvature can be carefully monitored.
- Highly oxygen permeable materials to improve corneal physiology

Nick Stoyan developed and patented the first of the "reverse geometry" lenses.

In 1989, **Wlodyga and Bryla**[33] introduced "**accelerated**" **orthokeratology** in a report on 15 patients fitted with a new series of reverse geometry lens designs manufactured by Contex. These lenses were designed with secondary curves steeper than their base curves. The steeper secondary curve served three purposes. The first was to provide space for the mid-peripheral cornea to move as the central cornea was flattened. The second purpose was to reduce lens decentration and the third was to create a tear reservoir to promote good tear exchange. Because of the reverse geometry, lenses could be fitted with base curves significantly flatter than those used in standard orthokeratology, resulting in larger and more rapid changes in corneal curvature and subsequent improvements in visual acuity.

Sami El Hage recommended the use of the term ‘controlled keratoreformation’ (CKR) to describe a method of orthokeratology that relied on measurements of the peripheral cornea by photokeratoscopy instead of keratometry.[34,35]

John Mountford developed the first effective computerized and predictable Ortho-k fitting regime in 1994.[2]

Anatomy of the Cornea

The cornea is a transparent, avascular watch glass like structure forming the anterior one sixth of the eyeball. It forms the principal refractive surface, contains the intraocular pressure and provides a protective interface with the environment. These functions can be subserved by virtue of a specialized substructural organization.[36]

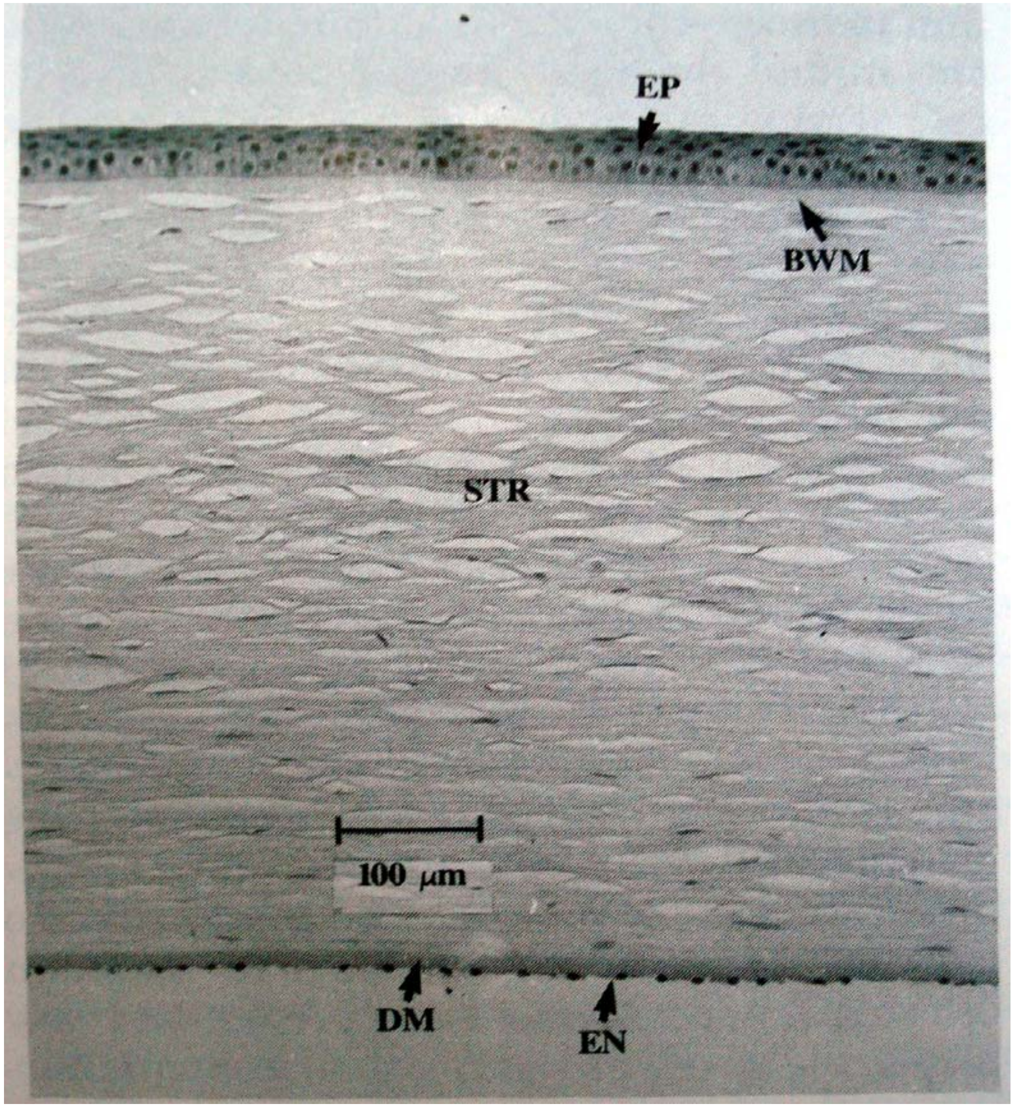
Histologically, the cornea is composed of five layers:

- Epithelium
- Bowman’s membrane
- Stroma or substantia propria
- Descemet’s membrane
- Endothelium

1. Corneal epithelium

It is stratified, squamous and non-keratinized. It is 50 to 90 micron thick and consists of 5 or 6 layers of nucleated cells. The epithelial cells are arranged in three zones:

- Deep zone: It consists of a single layer of basal columnar cells and forms the germinative zone.



- **Fig 1.** Photomicrograph of normal human cornea showing the stratified squamous epithelium (EP), Bowman's membrane (BWM), stroma (STR), Descemet's membrane (DM) and endothelium (EN) [37]

- Middle zone: It comprises of 2 to 3 layers of polyhedral cells called wing cells which are convex anteriorly and cap the basal cells.

- Superficial zone: It has 2 to 3 layers of flattened nucleated cells called squamous cells.

2. Bowman's layer

It is a narrow, acellular, homogeneous zone, 8 to 14 micron thick, simmediately subjacent to the basal lamina of the epithelium.

It is relatively resistant to trauma due to the compact arrangement of collagen but once destroyed, it can't be regenerated.

3. Stroma or substantia propria

It is around 560 micron thick (90% of the thickness of cornea) and comprises of regularly arranged lamellae of collagen bundles in a proteoglycan ground substance with cells called keratocytes.

The lamellar arrangement is less precise in the anterior stroma.

4. Descemet's membrane

It is a 10 to 12 micron thick basal lamina produced by the endothelium. It's peripheral termination is marked by the Schwalbe's line.

The major protein is type IV collagen. Descemet's membrane readily regenerates following injury.

5. Endothelium

It consists of a single layer of hexagonal cells lying on the Descemet's membrane. The normal endothelial cell density is 2500 to 3000 cells/mm^2

Turnover of corneal epithelial cells

The corneal epithelium is maintained by a constant cycle of shedding of superficial cells and proliferation of cells in the basal layer. The corneal epithelium is replaced approximately weekly by the division of the basal epithelial cells. The mitotic rate is 10 to 15% per day.[38]

The XYZ hypothesis of corneal epithelial maintenance

Thoft and Friend (1983) proposed, on the basis of experimental evidence, that there was both a limbal basal and a corneal basal epithelial source for corneal epithelial cells. The sequence of events from proliferation of stem cells to desquamation of superficial corneal epithelial cells is thought to involve cell division by the slow-cycling stem cells, whose daughter cells, the transient amplifying cells, migrate centripetally. They undergo limited series of cell divisions prior to terminal differentiation and ultimate shedding.[38,39]

X = proliferation of basal cells

Y = centripetal movement of cells

Z = cell loss from the surface

X + Y = Z

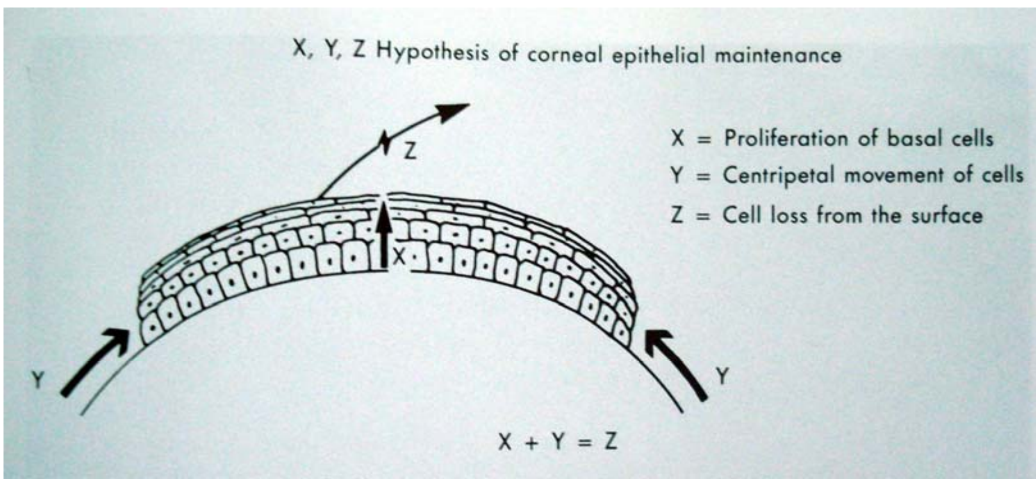


Fig 2. The X-Y-Z hypothesis of corneal epithelial maintenance

Corneal nutrition and metabolism[38]

Corneal metabolism depends on oxygen derived predominantly from the atmosphere with minor amounts supplied by the aqueous humour and limbal vasculature.[40]

The aqueous humour has lower oxygen content (approximately 40mm of Hg) as compared to that of tears (155mm of Hg). During sleep or under closed-eye conditions, oxygen is delivered to the cornea by the highly vascularised superior palpebral conjunctiva, albeit at reduced levels (i.e. PO_2 21% with eyelids open and 8% with eyelids closed).[41,42]

The corneal epithelium consumes oxygen at a rate approximately 10 times faster than the stroma does. Most of the metabolic requirements for glucose, amino acids, vitamins and other nutrients are supplied to the cornea by the aqueous humour, with lesser amounts available in the tears or via limbal vasculature. In addition the corneal epithelium has glycogen stores which can be a source of glucose.

Under both hypoxic and normoxic conditions, glucose derived from the aqueous humour or the epithelial glycogen stores is converted to pyruvate by the Embden-Meyerhof pathway (anaerobic glycolysis), yielding two molecules of adenosine triphosphate (ATP) per glucose molecule.

Under aerobic conditions, pyruvate is then oxidized in the tricarboxylic acid cycle (Krebs or citric acid cycle) to yield water, carbon dioxide and 36 molecules of ATP per cycle.

Under hypoxic conditions, such as during contact lens use, increasing amounts of pyruvate are converted by the enzyme lactate dehydrogenase to lactate, which diffuses from the epithelium into the stroma, osmotically inducing epithelial and stromal oedema.[43] Epithelial oedema leads to clinical symptoms such as halo and rainbow formation, increased glare sensitivity and decreased contrast sensitivity.

Because of the barrier provided by the superficial epithelial cells, the dispersion of lactate into the tear film is precluded and the elimination of lactate is dependent on slow diffusion across the stroma and endothelium into the aqueous humour.

It has been shown that the cornea can maintain a deturgescent state with sustained oxygen levels as low as 25mm of Hg before oedema is induced.[44]

For small diameter hard polymethyl methacrylate lenses which are impermeable to oxygen, good lens movement is essential to allow an exchange of tears under the lens with oxygenated tears from the periphery which is accomplished by the action of the lid blink. For larger diameter soft lenses, especially those used on an extended –wear basis, oxygen permeability must be sufficient for an adequate supply of oxygen to reach the cornea by diffusion through the lens itself, in addition to the lesser effect of the tear pump exchange with these lenses.[38]

Corneal Cap

The anterior curvature of the cornea is spherical over a small zone 2 to 4 mm in diameter which is decentred upwards and outwards relative to the visual axis, but correctly centred for the pupillary aperture (which lies 0.4 mm temporally). This is termed the “corneal cap” or “corneal apex”. The corneal curvature varies from apex to limbus. There is greater flattening nasally than temporally and above than below, although variations occur. Near the limbus, the corneal curvature increases before entering the trough-like contour of the limbal zone. These features influence the fitting of contact lenses.[45]

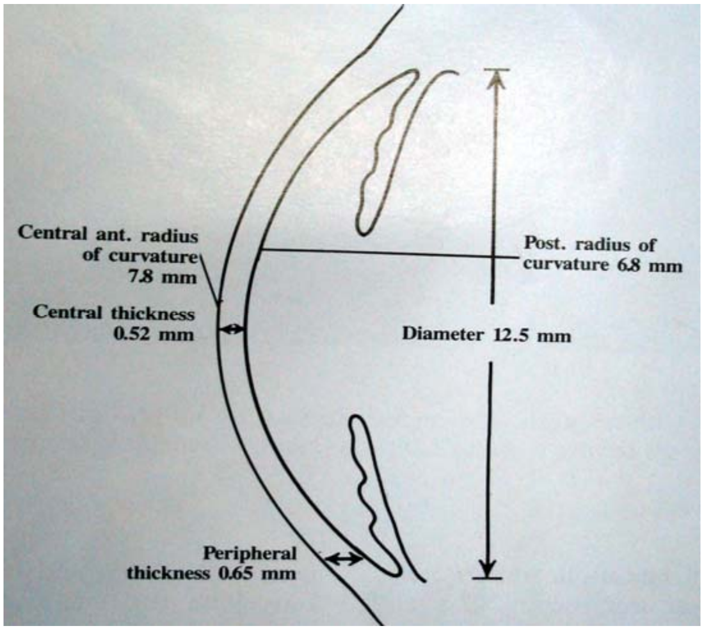


Fig 3. Corneal dimensions[37]

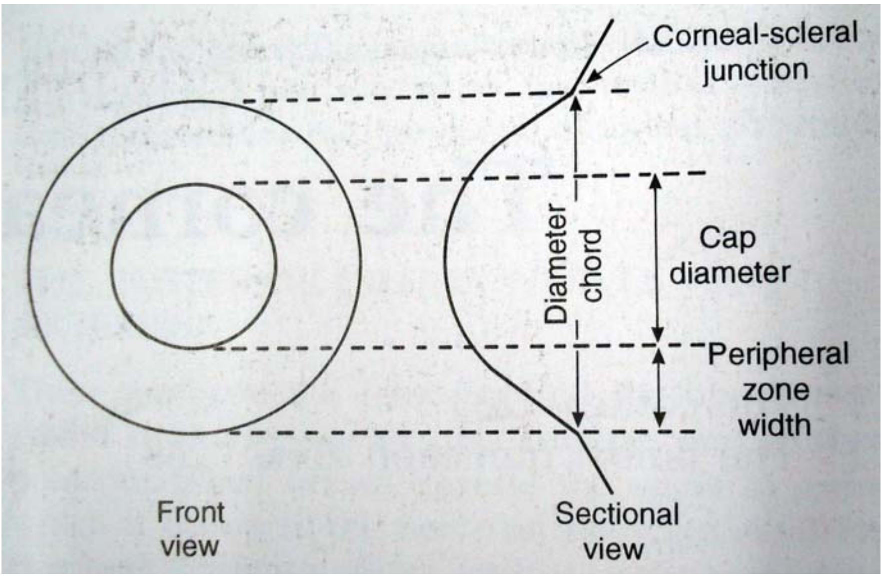


Fig4. Corneal cap on topography

MYOPIA[46]

Myopia, or short sight, is that form of refractive error wherein parallel rays of light come to a focus in front of the sentient layer of the retina when the eye is at rest; the eye is thus relatively too large.

Types of myopia:

1. Axial myopia : due to an increase in the antero-posterior diameter of the eye

2. Curvature myopia : due to the increase in the curvature of the cornea or one or both surfaces of the lens

3. Index myopia : due to a change in the refractive index of the lens

In a great majority of cases, myopia is of the axial variety which occurs due to the antero-posterior lengthening of the eyeball.

Complications of myopia

- Muscae volitantes
- Tears and hemorrhages in the retina
- Retinal detachment
- Posterior cortical cataract
- Posterior staphyloma

Myopia can be treated with spectacles, contact lenses and refractive surgeries. Orthokeratology uses specific types of RGP contact lenses which attempt to correct myopia by flattening the anterior corneal surface as a compensation for the enlarged eyeball.

Orthokeratology

Orthokeratology makes use of specially designed RGP lenses for the correction of myopia. These lenses can be used for low degrees of astigmatism and hypermetropia too.

Lens material[47]

The lenses are made from a fluorosilicone acrylate polymer with a water content of less than 1%. This material has a high oxygen permeability or a high Dk value. The other materials used are Paragon HDS, Paragon HDS 100, Boston XO and Boston equalens II.

Lens design[47]

Orthokeratology lenses have evolved significantly over the years.

First generation ortho-k lenses

These were conventional rigid contact lenses fit as flat as possible. The disadvantages of these lenses were as follows:

- The extremely flat fit resulted in the decentration of the lenses either up or down causing corneal distortion and increased astigmatism.

- The material used for these lenses was polymethyl methacrylate (PMMA) which lacked good oxygen permeability and did not allow for overnight wear. Prolonged wear of such lenses also led to corneal oedema and further corneal distortion.

- The fitting procedure involved making very small incremental lens design changes. This process was slow, expensive and tedious for both the fitter and the patient.

- Myopia reduction did not last very long when lenses were worn occasionally on a daily wear basis.

Second generation ortho-k lenses

These are special types of contact lenses called “reverse geometry lenses” (RGLs). With the advent of computer assisted lathes, it has become feasible to manufacture RGLs with the secondary curve steeper than the back optic zone radius (BOZR).

The advantages of these lenses are as follows

- They make myopia reduction more predictable and achievable.

- They attain good centration and optimal pressure distribution under the lens.

- Since the materials used have high oxygen permeability, it allows for overnight wear of the lenses.

- The reverse geometry designs are also found to be useful in fitting post-refractive surgery cases and post-penetrating keratoplasty cases as opposed to the conventional gas permeable or soft lenses.

The disadvantages are as follows

- Improperly fitted lenses induce ‘with-the-rule’ astigmatism and the patients may have diplopia and glare when the pupils become larger.

Types of Reverse Geometry Lenses[47]

- Three curve RGL
- Four curve RGL
- Five curve or double RGL
- Six curve RGL

Various curves of the RGL[47]

Base curve / Treatment zone

It flattens the central portion of the cornea and should be at least 4mm in diameter.

Reverse zone

It is the steepest part of the lens and marks the transition between the base curve and the alignment zone.

Alignment zone

It centres the contact lens on the cornea and is also referred to as the ‘fitting curve’.

Peripheral zone

An aspheric ski edge lift allows good tear exchange and ensures patient comfort.

- Three curve RGLs have a base curve, reverse zone and peripheral zone.
- Four curve RGLs have a base curve, reverse zone, alignment zone and peripheral zone.
- Five curve RGLs have a base curve, reverse zone, two curves in the alignment zone and peripheral zone.
- Six curve RGLs have a base curve, reverse zone, two curves in the alignment zone and two in the peripheral zone.

Most patients treated with modern ortho-k lenses achieve their desired myopia reduction with only one pair of lenses as compared to the old process that often took many pairs to achieve the same.

Mechanism of action[47]

It is presumed that the ortho-k lenses reshape the cornea by moving the epithelial cells from the centre to the periphery, thus flattening the anterior surface.

The amount of flattening is roughly 6 microns per dioptre of myopia.

Ortho-k works by means of a squeeze film force beneath the lens acting tangentially across the corneal epithelium which gets thinned centrally and redistributed towards the mid-periphery. In other words, the thin layer of tear film that exists between the back of the ortho-k lens and the central cornea has “shear forces” that act hydraulically to force a redistribution of epithelial cells under the lens from the centre toward the periphery.

Studies conducted by Helen Swarbrick[48] et al, of the University of New South Wales, Sydney, Australia in 1998 evaluated topography and pachymetry changes in accelerated orthokeratology lens wearers over a 30 day period. Their study found:

- Corneal epithelial cells were redistributed to significant levels across the corneal surface leading to a thinning of the central cornea.

- There was concurrent thickening of the midperipheral cornea, particularly in the stromal layer.

- These changes occurred with no apparent change in the posterior corneal curvature.

The tear film forces cause a compression that results in redistribution of the epithelial cells and probably some stromal fibrils towards the corneal periphery. This produces a reduction in the corneal sagittal depth which results in a shortening of the axial length of the eye.

Because there is thinning of the central cornea, there are some similarities with laser refractive surgery, which uses the **Munnerlyn formula** to predict how much tissue needs to be removed. This is now also used in orthokeratology as the most reliable way of predicting the refractive change[10]:

$A = (RD^2) / 3$

where A = ablation depth (or corneal thinning)

R = refractive error

D = diameter of the treatment zone

The maximum change in epithelial thickness has been suggested as 20 micron compared with the total thickness of the corneal epithelium of approximately 50micron. Using this figure of 20micron for treatment zones of 6mm and 4mm, the anticipated refractive changes would be respectively -1.75D and -3.75D.

Myopic orthokeratology: The posterior shape of the ortho-k lens creates a positive push force which flattens the centre of the cornea. The mid peripheral cornea, on the other hand, is subjected to a negative pressure or pull.

Hypermetropic orthokeratology works on the exact opposite mechanism wherein the central portion of the cornea is steepened.

Two types of Ortho K lenses are approved by the FDA:

1. Corneal Reshaping Therapy (**CRT**) from Paragon Vision Sciences
2. Vision Shaping Treatment (**VST**) from Bausch and Lomb

These lenses can be used either as day wear lenses or for overnight wear. Patients readily accept overnight ortho-k because adaptation is rapid with minimal lens awareness.

Indications and Patient selection[47]

- ✓ Young, emerging myopes

[FDA approval:

For CRT: myopia of -6.00D and astigmatism of upto -1.75 D

For VST: myopia of -5.00D and astigmatism of upto -1.50 D]

- ✓ Adolescents and teens who are not eligible for LASIK
- ✓ Sports men, Swimmers
- ✓ People who work in dusty, dirty environments
- ✓ Alternative to spectacles and daily wear contact lenses
- ✓ Vocational requirement of unaided visual acuity for certain periods such as police, firemen, military etc
- ✓ High corneal *e*-values, over 0.50

There is no age restriction but generally patients who are seven years or older are preferred.

Contraindications[47]

- ✓ Acute and subacute inflammations or infections of the anterior segment
- ✓ Any disease, injury or abnormality that affects the cornea, conjunctiva or eyelids
- ✓ Severe dry eyes
- ✓ Corneal hypoaesthesia
- ✓ Systemic disease that may affect the eye or be exacerbated by wearing contact lenses
- ✓ Allergy to ingredients of contact lens solutions
- ✓ Any active corneal infection – bacterial, fungal or viral
- ✓ Loose eyelids where there is minimal force to mould the corneal shape

The amount of myopia reduction depends upon:

- Original K readings
- Amount of myopia
- Elastic characteristics of the cornea
- Rigidity factor of the cornea
- Fitting of the contact lens
- Duration of lens wear
- Corneal rheology of the individual patient

Ideal candidates

- ✓ Myopia 0.50 D to 3.00 D
- ✓ -1.50 D astigmatism or less with the rule
- ✓ Young emerging myopes
- ✓ Sportsmen
- ✓ Children who are not candidates for surgery

- ✓ Adults with an active lifestyle who do not want the option of surgery

Poor candidates

- ✓ Against the rule astigmatism -0.75 D or more
- ✓ Topography showing extreme steep portion of a quadrant
- ✓ Astigmatism more than half the spherical correction
- ✓ With the rule astigmatism more than -1.50 D
- ✓ Internal or lenticular astigmatism
- ✓ Large pupils where flare may be a problem
- ✓ Low corneal *e*-values
- ✓ Unrealistic patient expectations

Pre fitting evaluation

Spectacle wearers can be fitted with ortho-k lenses immediately. RGP lens wearers should discontinue the lenses for three weeks and soft lens users should discontinue it for one week before the ortho-k lens fitting.

The pre fitting examination should include:

- The uncorrected and best corrected visual acuity
- A detailed slit lamp examination including an assessment of the pupil diameter
- Ophthalmoscopy
- Baseline corneal topography
- Tear film analysis

  a) Schirmer’s test (quantitative)

  b) Tear film Break-Up time or TBUT (qualitative)

Fitting procedure

The fitting of ortho-k lenses is based on the patient's refractive error and corneal topographic flat K value.

The ortho-k lens to be fitted is chosen with the help of a nomogram.

Example

The Base Curve calculation is as follows:

Flat 'K' 44.00

Refractive error -3.00

- Flat 'K' 44.00
- Sphere minus one diopter -3.00 -1.00 = - 4.00

  40.00
- Base curve to order is 40.00 D

Original flat 'K' 44.00 D	1st Choice Inventory lens **K13**
Target power -3.00 D	Base Curve 40.00 D (8.43mm)
Eccentricity value 0.4	Target power -3.00 D

The ideal fit[47]

The treatment zone has the target power and the BOZR is flatter than the flat K value by one dioptre.

The reverse curve is usually 0.60mm to 1.00mm wide.

The alignment curve is around 0.80mm to 1.50mm wide and may be spherical, aspheric or a tangential straight line.

The peripheral curve is approximately 0.30mm wide.

The fit is evaluated after staining with 2% Fluorescein. An ideal fit shows a central zone of applanation and 360degree mid-peripheral pooling.

<u>Characteristics of an ideal fit:</u>

- Well centered lens
- Broad applanation of atleast 4 mm
- Narrow tear channel under the reverse zone
- Wide alignment zone
- Moderate edge lift with good tear exchange
- Slight movement after blinking (1mm)

Patients should be instructed in lens removal both by the manual blink method and by the use of the silicone rubber lens remover.

The patient is then allowed to wear the lenses overnight and reviewed the next morning.

The centration and movement of the lens are assessed.

The unaided and best corrected visual acuity is noted.

Corneal topography is done to determine centration of the lens and the amount of flattening achieved. The "bull's eye" pattern indicates that the lens is well centered both horizontally and vertically.

A slit lamp examination is performed and side effects, if any, are enquired into.

A significant degree of myopia reduction often occurs after the first night. If the initial lens appears to have tightened, a flatter lens should be fitted. It may also be necessary to repeat the trial with a different lens because of an unsatisfactory result. This may consist of:

- Borderline or minimal improvement in unaided vision
- An insignificant reduction in myopia
- Unacceptable lens decentration

- Corneal distortion
- Corneal staining even with a well-fitting lens
- Excessive dimpling

The initial goal in ortho-k lens fitting is to achieve the desired amount of myopia reduction. Having reached that point, the goal is then to try to reduce overnight lens wear to a frequency that will still maintain the desired visual acuity level and a stable corneal shape.

The follow up examination schedule is as follows:

- Next day
- 1 week
- 1 month
- 3 months
- 6 months
- 1 year

The patient should wear or bring his/her contact lenses into the office for each exam visit.

Ortho-k lens care and handling[47]

The patients must be thoroughly trained to wear and care for their ortho-k lenses using proper hygienic methods whenever the lenses are handled.

Preparing the lens for wearing:

- Always wash, rinse and dry hands thoroughly before handling contact lenses.
- Avoid oily soaps, lotions or oily cosmetics prior to handling lenses. These substances can adhere to the surface of the lenses and be difficult to remove.
- Handle lenses with the fingertips, avoiding the use of fingernails because they can scratch or chip the lenses.
- Always start with the same lens first to avoid mix-ups.
- Remove the lens from its storage case and examine it to see if it is clean, moist and free of any cracks or nicks.

Placing the lens on the eye:

After thoroughly washing and drying hands, these steps are followed to place the lens on the eye –

- Remove the lens from the case.
- Rinse the lens with fresh conditioning solution.
- Inspect the lens for cleanliness, uniform wetness and unwanted debris.
- Rub several drops of fresh conditioning solution over the surface of the lens.
- Place the lens on the top of the index finger of the dominant hand.
- Hold down the lower lid with the middle finger of the dominant hand and lift the upper lid with the other hand.
- Gently place the lens on the centre of the eye, release the lids and blink. With this, the lens should centre automatically.
- Use the same technique to insert the other lens.
- The wearer should be instructed to place two or three drops of the recommended wetting solution in each eye before sleeping.

Removing the lenses:

- The lens may be removed manually by using the “blink” or “scissor” method as with standard RGP lenses.

- The removal of large diameter ortho-k lenses may require the use of a soft silicon rubber removal device.

Before attempting to remove a lens, one should verify whether the lens is moving. Because of the overnight wear, the lens may be bound in place on the eye in the morning.

If the lens is stuck, few drops of the recommended lubricating solution are applied to the eyes in the morning. After a few minutes, when the lens begins to move freely with the blink, its removal should be attempted.

If the adhered lens does not move freely after applying the lubricating drops, it should be loosened manually. While looking upwards, a finger is placed at the lower eyelid at the lens edge to gently but firmly apply pressure. Looking downward, the process is repeated using the fingertip placed on the upper eyelid at the lens edge. The patient should then look straight ahead and blink several times. Once the lens begins to move, it can be removed.

Cleaning and storing the lenses:

- The lenses should be rubbed gently for 20 seconds on each side with the recommended multipurpose solution, followed by a thorough rinse in the same.

- Care must be taken not to press or squeeze the lenses excessively during and handling since they are susceptible to distortion and breakage.

- The cleaned lenses should be placed in the proper well of the lens case and covered completely with the storage solution, allowing them to soak for a minimum of four hours.

Problems with ortho-k lens fitting:[47]

1. High riding lens:

This occurs if the alignment curve is too flat or with an excessively tight upper lid.

It can be corrected by

- Steepening the alignment curve with a comparable adjustment to the reverse curve
- Increasing the overall sag of the lens
- Increasing the lens mass with a greater centre thickness, incorporating a prism or using material of higher specific gravity
- Steepening the radius of the front surface lenticulation to reduce the effect of the upper lid or adjusting edge shape and thickness

2. Low riding lens:

This occurs if the alignment curve is too steep or with lid pressure or gravity.

It can be corrected by

- Flattening the alignment curve with a comparable adjustment to the reverse curve
- Decreasing the overall sag of the lens
- Decreasing the lens mass with a reduced centre thickness or using material of lower specific gravity
- Adjusting the edge shape, thickness or lenticulation to increase the upward effect of the lid

3. <u>Lateral decentration:</u>

It may be caused by a flat alignment curve, against the rule astigmatism or a decentred corneal apex.

It can be corrected by

- A larger total diameter of the lens
- A steeper alignment curve
- Increasing the overall sag of the lens

4. Vaulting and air bubbles:

This may be addressed by choosing a flatter lens.

5. Over-responders:

The target power or the wearing time of the lens maybe reduced to tackle this problem.

6. Under-responders:

The target power or the wearing time of the lens should be increased to deal with this problem.

7. Central islands:

These are areas of incomplete treatment caused by a steep fitting or resistant areas of the cornea. They give rise to reduced acuity or distorted vision.

This can be corrected by

- A flatter fitting to increase the area of central touch
- Improving centration
- Reducing the overall sag of the lens

8. Smiley face and Frowny face:

The ‘smiley face’ pattern is usually found inferior to the central treatment zone. It represents areas of localized corneal steepening caused by a flat fitting which in turn allows a superior lens decentration. The ‘frowny face’, on the other hand is seen superior to the central treatment zone and occus due to superior corneal steepening.

This can be corrected by

- A steeper fitting
- A larger total diameter of the lens
- Increasing the overall sag of the lens

9. Corneal stippling:

It occurs when the central or peripheral part of the alignment zone is too tight preventing proper tear exchange.

A flatter alignment zone should be chosen to address this problem.

10. Lens adhesion:

This is experienced by a fairly high percentage of patients.

A lens that adheres may be improved by:

- Using a smaller total diameter
- Altering the alignment curve in relation to any lens decentration
- Flattening the peripheral curve to increase the edge lift

11. Induced astigmatism:

Is the result of a decentred lens. Alterations should be made in the alignment curve according to the type of decentration to correct the induced astigmatism.

The role of corneal topography in ortho-k lens fitting:

Corneal topography is an integral part of the ortho-k lens fitting and aftercare procedures. The axial, subtractive and numeric plots are the most useful in orthokeratology.[10]

There are two basic methods of measurement of corneal curvatures:[49]

1. Reflection (Placido disc) based systems:

They measure the slope of the corneal surface and can use this information to calculate the radius of curvature and power. They do not measure elevation.

Examples - Keratometer and Videokeratoscope

2. Projection based systems:

They measure the true corneal shape in terms of elevation from which slope, curvature and power can be calculated.

Examples - Slit scanning photography, Rasterstereography, Moires interference, Laser interferometry

Bogan and colleagues classified the computerized videokeratography patterns of normal human corneal topography as follows:[50]

- Round – 22.6%
- Oval – 20.8%
- Symmetric bowtie – 17.5%
- Asymmetric bowtie – 32.1%
- Irregular – 7.1%

Topographic indices[51,52]

SIM K1 (K_s) and **SIM K2 (K_f)** are powers on strong and weak principal meridians at a radial position of about 3 mm on the cornea. These values are calculated by averaging the measured values of the 8 to 10th rings on the meridian. Numerical values higher than the normal value predict keratoconus, cornea-transplanted eyes, and natively steep corneas. Numerical values lower than the normal values predict myopia-corrected post LASIK corneas and natively flat corneas.

MIN K (Minimum keratometry value) is the lowest power of the powers at a radial position of 3 mm on the cornea. In some corneas with irregular astigmatism, strong and weak principal meridians are not present in 90 degree directions. This will become an important factor during surgery for correction of astigmatism.

CYL (Simulated keratometric cylinder) is the corneal cylinder power obtained as the difference between SimK1 and SimK2 (K_s and K_f respectively)

SAI (Surface Asymmetry Index) is obtained by measuring the difference in refractive values at a position of 180 degrees symmetry to each ring over the entire corneal surface. An SAI value of greater than 0.5 is considered abnormal.[53] Higher than normal SAI values are induced by keratoconus, penetrating keratoplasty, myopic refractive surgery, trauma or warped contact lens.

SRI (Surface Regularity Index) indicates a local variation in the centre of the cornea and is a value associated with **PVA (potential visual acuity)**. An increase in SRI means that the corneal surface within the pupil radius is irregular. A value greater than 1.0 is considered abnormal.[53] Dry eyes, corneal deformation due to wearing of contact lenses and cornea-transplanted eyes indicate high values. **SRC (Area compensated SRI)** is an index obtained by correcting SRI by the area of the subject to be analyzed.

ACP is the **average corneal power** within the entrance pupil. This can be regarded as the spherical equivalent value of the cornea. If the keratometry value is abnormal, ACP also takes an abnormal value.

CEI (Corneal Eccentricity Index) indicates asymmetry of the cornea. A positive value indicates a prolate cornea. 0 (a nil value) indicates a spherical cornea. A negative value indicates an oblate cornea. A keratoconus shows a positive value much higher than those of normal corneas. Corneal deformation due to wearing of contact lenses and myopia corrected post LASIK eyes show negative values.

CVP (Coefficient of variation of corneal power) is a numerical value indicative of an index created from the power distribution over the whole region on the cornea and calculated from the following formula. *CVP*= 1000×(standard deviation SD of powers over the whole region on cornea/average power over the whole region on cornea).

Where the value of the CVP is high, the cornea shows a multifocal nature as seen in moderate to advanced keratoconus.

SDP (Standard Deviation of corneal power) is calculated from a distribution of all corneal powers in the videokeratograph. It is high in keratoconus, trauma and transplants.

IAI (Irregular Astigmatism Index) is an area compensated average summation of inter ring power variations along every meridian for the entire corneal surface analyzed. It has high values after penetrating keratoplasty.

I-SV (Inferior – Superior value) is calculated from the refractive power difference between five inferior and five superior points 3mm from the centre at 30 degree intervals.

Analyzed Area gives the fraction of the corneal area covered by the mires that could be processed by the auto topographer.

The measurement of corneal topography is essential because:

- It provides measurements for the apical radius and eccentricity.
- It can help predict potential failures prior to fitting from these measurements.
- It can provide a permanent record of corneal shape and power at all stages of the procedure.
- The subtractive plot gives a record of the progress.

- It demonstrates graphically any unacceptable degree of corneal distortion either before or during fitting.

- The type of distortion gives indications as to whether the fit is flat, steep or decentred.

AIMS OF THE STUDY

a) To determine the amount of refractive correction after single overnight application of OrthoK lenses in myopes with and without low degrees of astigmatism

b) To assess corneal topographic changes after overnight orthokeratology

c) To determine the duration of maintenance of clear vision during daytime after a single application of OrthoK lenses

d) To evaluate the side effects of OrthoK lens wear

e) To assess the effectiveness of orthokeratology in the refractive correction of keratoconus patients

INCLUSION CRITERIA

- Myopia (-1.0D to -10.0D) with or without astigmatism of -0.25D to -1.0D
- No prior history of use of RGP contact lenses
- In case of soft lens users, lens wear was discontinued for 1 week before OrthoK fitting
- No prior documented history of anterior segment inflammation

EXCLUSION CRITERIA

- Myopes with presbyopia
- Astigmatism > 1.0D
- History of corneal refractive surgery
- History of allergic reactions following soft contact lens wear

MATERIALS AND METHODS

This study was conducted at the Regional Institute of Ophthalmology and Government Ophtahalmic Hospital, Chennai between February 2008 and October 2008.

40 eyes of 20 patients were included in the study.

OrthoK lens fitting was done according to the topographic flat K value and the spherical equivalent of the refractive error.

Corneal topographic parameters were assessed with TMS Tomey version 4.

The patients were reviewed the morning after a single OrthoK lens application. The uncorrected visual acuity, best corrected visual acuity and topography were recorded. A detailed ocular and slit lamp examination was performed.

They were asked about side effects, if any.

Five patients were followed up every week for a period of 1 month and then every month for 3 months. At each visit, the unaided and best corrected visual acuity was assessed. Corneal topography was performed to look for centration of the treatment area and consistency in the various parameters. A slit lamp examination was also performed to look for any adverse reactions.

OBSERVATION AND ANALYSIS

The results were analyzed as follows:

1. **The amount of refractive correction achieved after single overnight application of OrthoK lenses**

Table 1

Spherical equivalent (dioptres)	**No. of eyes**	**Percentage**
0.0 to 1.0	3	7.5%
1.0 to 2.0	20	50%
2.0 to 3.0	14	35%
3.0 to 4.0	3	7.5%

The data shows that 50% of the eyes achieved between 1.0 to 2.0D of myopic correction after overnight orthokeratology, 35% achieved between 2.0 to 3.0D and 7.5% each between 0 to 1.0D and 3.0 to 4.0D of myopic correction.

The mean spherical equivalent refractive correction achieved was -2.05D.

Refractive correction achieved after a single session of overnight orthokeratology

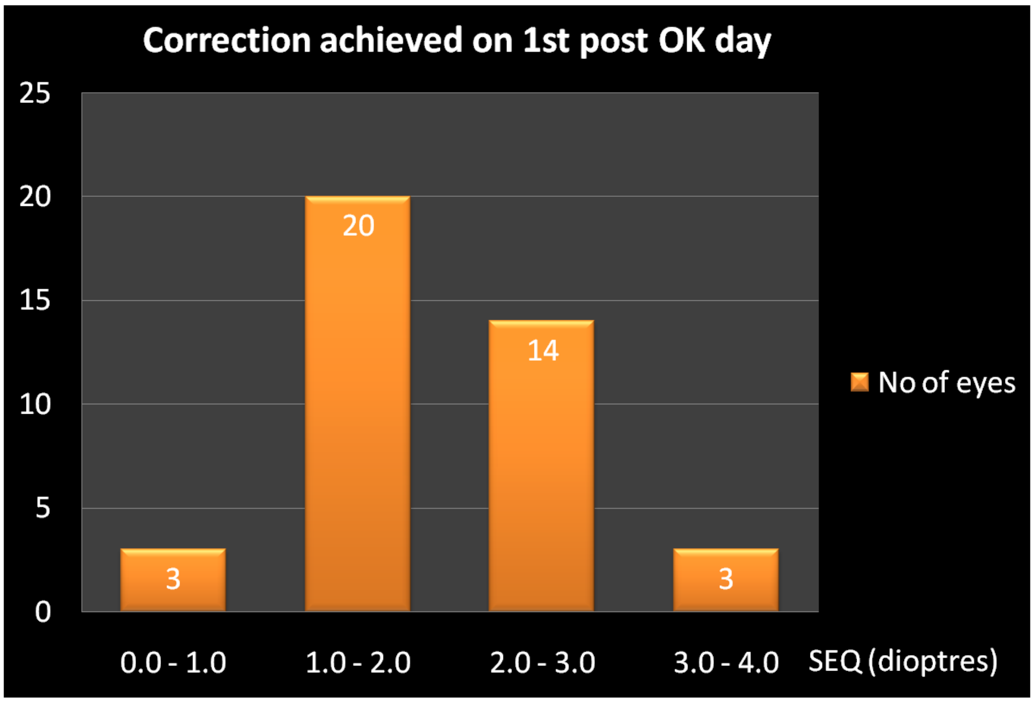


Fig 1. shows that 50% of the eyes achieved 1.0 to 2.0D of myopic correction and another 35% achieved 2.0 to 3.0D of myopic correction after overnight ortho-k lens wear.

2. The amount of reduction in the topographic average K reading after a single overnight OrthoK lens application

Table 2

Reduction in average K value (dioptres)	**No. of eyes**	**Percentage**
0.0 to 0.5	3	7.5%
0.5 to 1.0	5	12.5%
1.0 to 1.5	8	20%
1.5 to 2.0	13	32.5%
2.0 to 2.5	9	22.5%
2.5 to 3.0	2	5%

The majority of patients (32.5%) experienced 1.5 to 2.0D of reduction in the topographic average K value after overnight orthokeratology. 22.5% had a reduction of 2.0 to 2.5D, 20% had a reduction of 1.0 to 1.5D, 12.5% had a reduction of 0.5 to 1.0D, 7.5% upto 0.5D and 5% between 2.5 to 3.0D in their average K readings.

Reduction in the topographic average K reading after a single overnight orthokeratology session

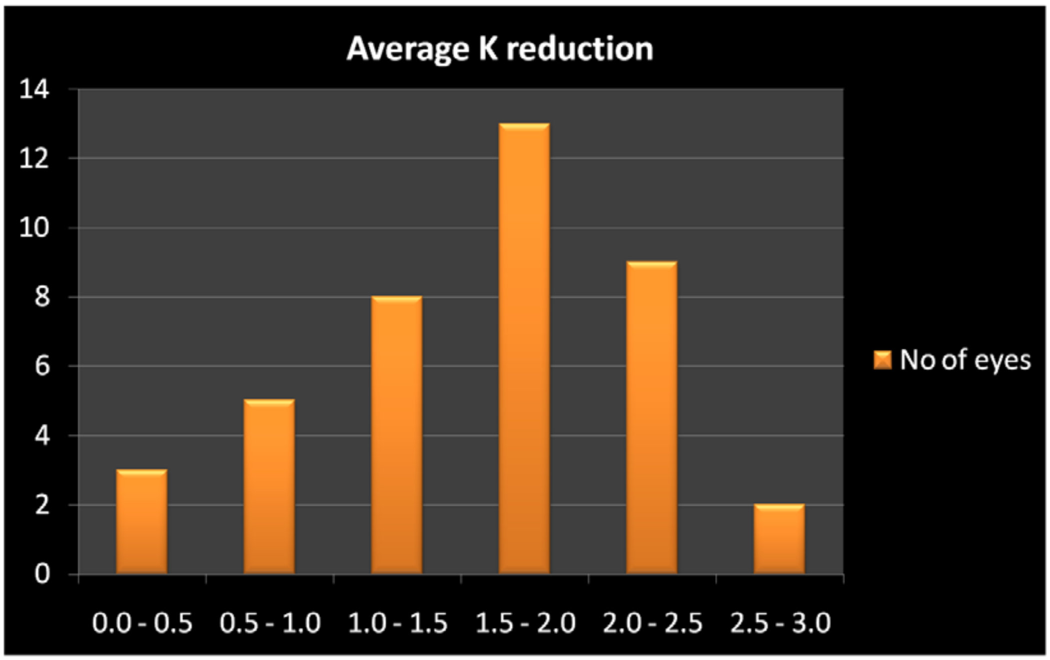


Fig 2. shows that 13 patients (32.5%) had 1.5 to 2.0D of reduction in their topographic K reading after overnight ortho-k lens wear and another 9 patients (22.5%) between 2.0 to 2.5D of reduction.

3. The change in corneal eccentricity values after single overnight ortho-k lens application

Our patient data demonstrated that the corneal eccentricity values tended to become less positive or more negative after a single overnight orthokeratology session. This is coherent with the desired change in shape of the cornea from the normal prolate to the centrally flattened oblate shape.

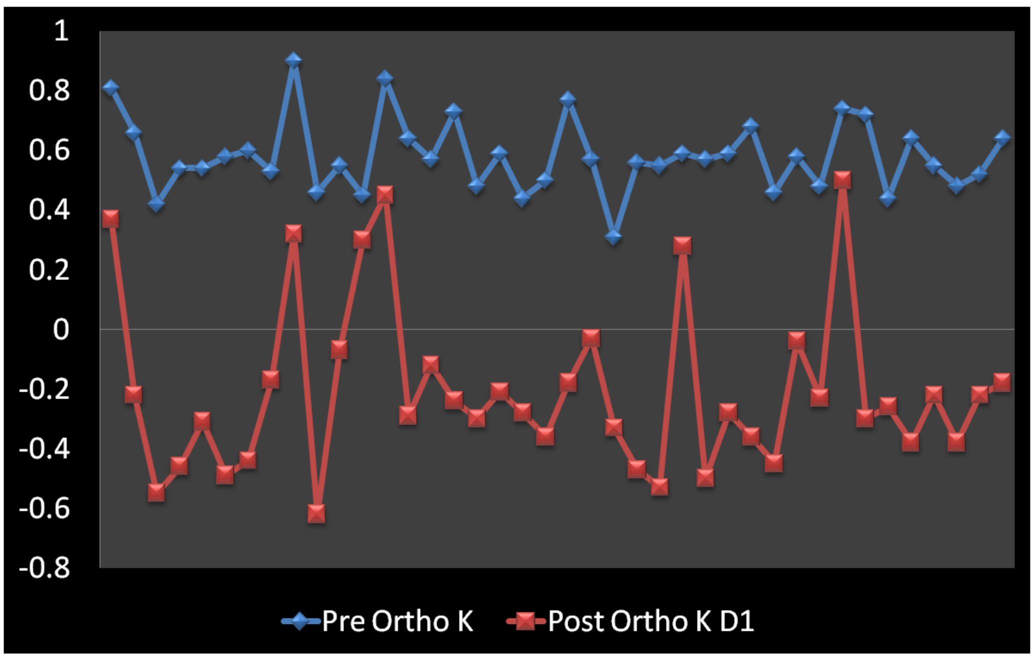


Fig 3. shows the trend towards more negative values of corneal eccentricity after single overnight ortho-k lens application indicating a change in shape from prolate to oblate

4. **The changes in Surface Regularity Index (SRI) following a single overnight application of ortho-k lenses**

The SRI values increased after overnight orthokeratology but did not exceed the values considered as normal (i.e. all the values were below 1.0). This caused no significant visual impairment.

SRI changes following overnight orthokeratology

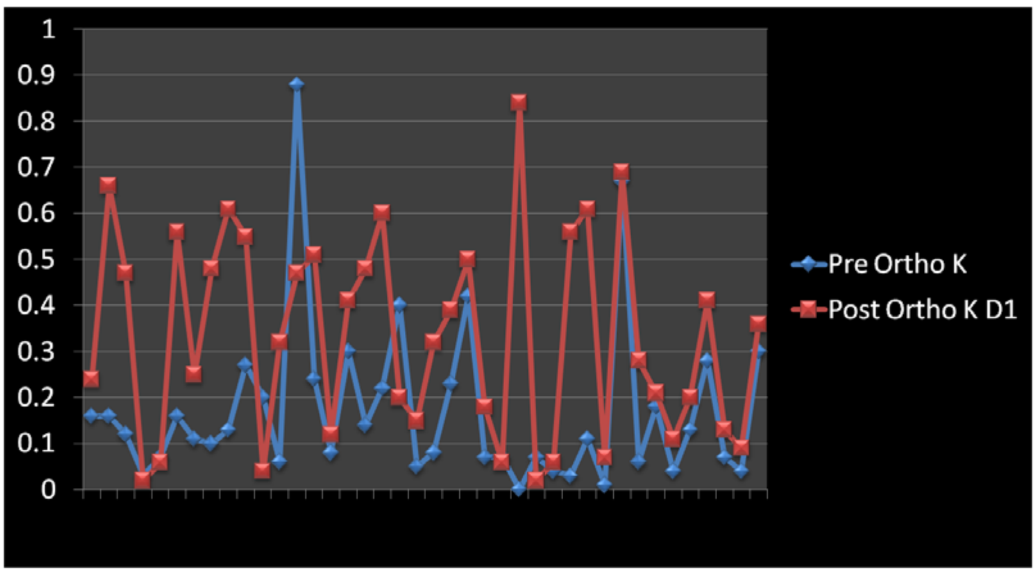


Fig 4. shows that the SRI values increased after overnight orthokeratology but were still within the normal limits (less than 1.0).

5. **The changes in Surface Asymmetry Index (SAI) following a single overnight application of ortho-k lenses**

The SAI values increased after overnight orthokeratology and exceeded the normal cut-off limit of 0.5 but this asphericity caused no significant visual impairment.

SAI changes following overnight orthokeratology

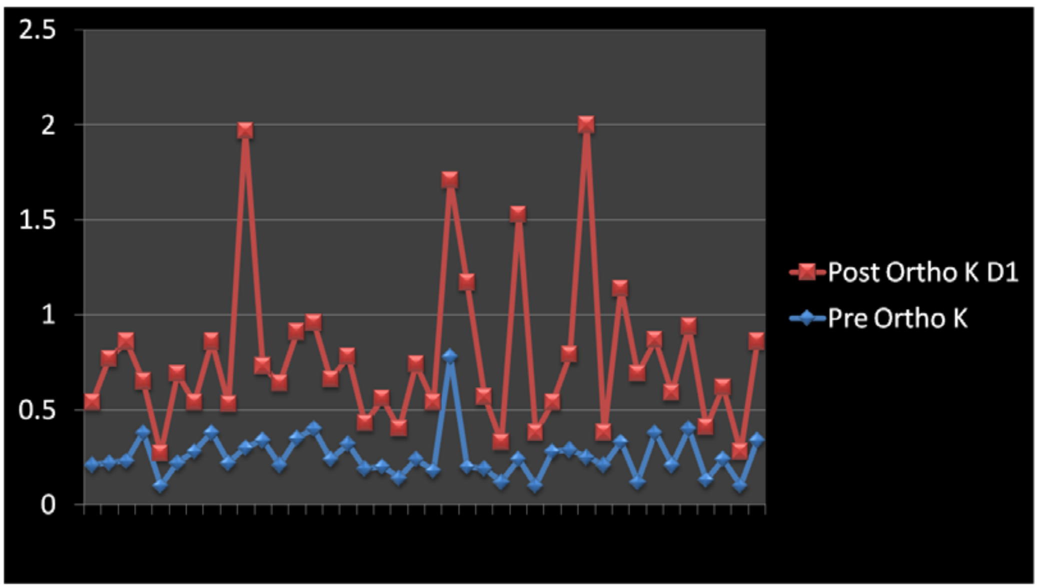


Fig 5. shows that the SAI values increased beyond the normal limit after overnight orthokeratology indicating a trend towards more asphericity.

6. The duration of unaided clear vision during daytime after one overnight orthokeratology session

Table 3

Duration of clear vision	**No. of patients**	**Percentage**
4 to 6 hours	3	15%
6 to 8 hours	12	60%
8 to 10 hours	3	15%
10 to 12 hours	2	10%

60% of the patients had 6 to 8 hours of unaided clear vision during the day after one night of ortho-k lens wear. 15% patients experienced 4 to 6 hours and 8 to 10 hours of unaided clear vision each and 10% had 10 to 12 hours of clear vision during the day.

Duration of unaided clear vision during the day after one night of orthokeratology

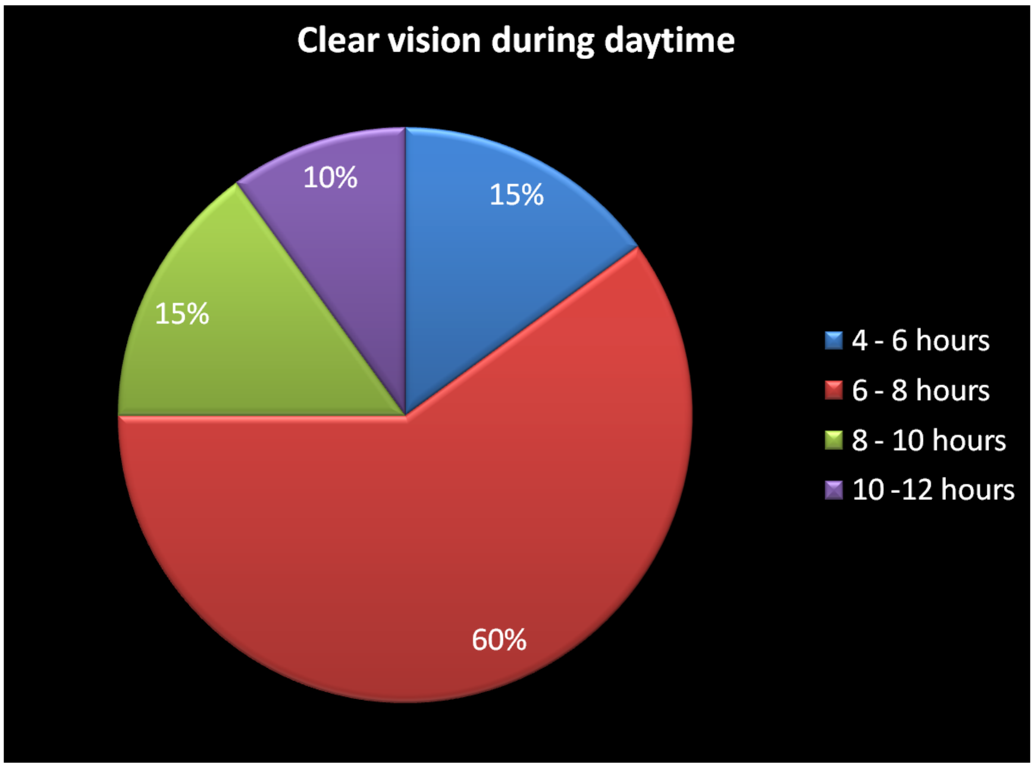


Fig 6. shows that the majority of our patients (60%) had unaided clear vision that lasted for 6 to 8 hours following a single overnight ortho-k lens application.

7. The occurrence of side effects after overnight orthokeratology

Table 4

Side effects	No. of patients	Percentage
None	13	65%
Irritation	3	15%
Heaviness of eyelids	2	10%
Epithelial erosion	1	5%
Haloes	1	5%

Overnight orthokeratology was not associated with any side effects in 65% of our patients. 15% patients experienced ocular irritation, 10% had heaviness of eyelids and 5% each (1 patient each) developed epithelial erosion and haloes.

The occurrence of side effects after overnight orthokeratology

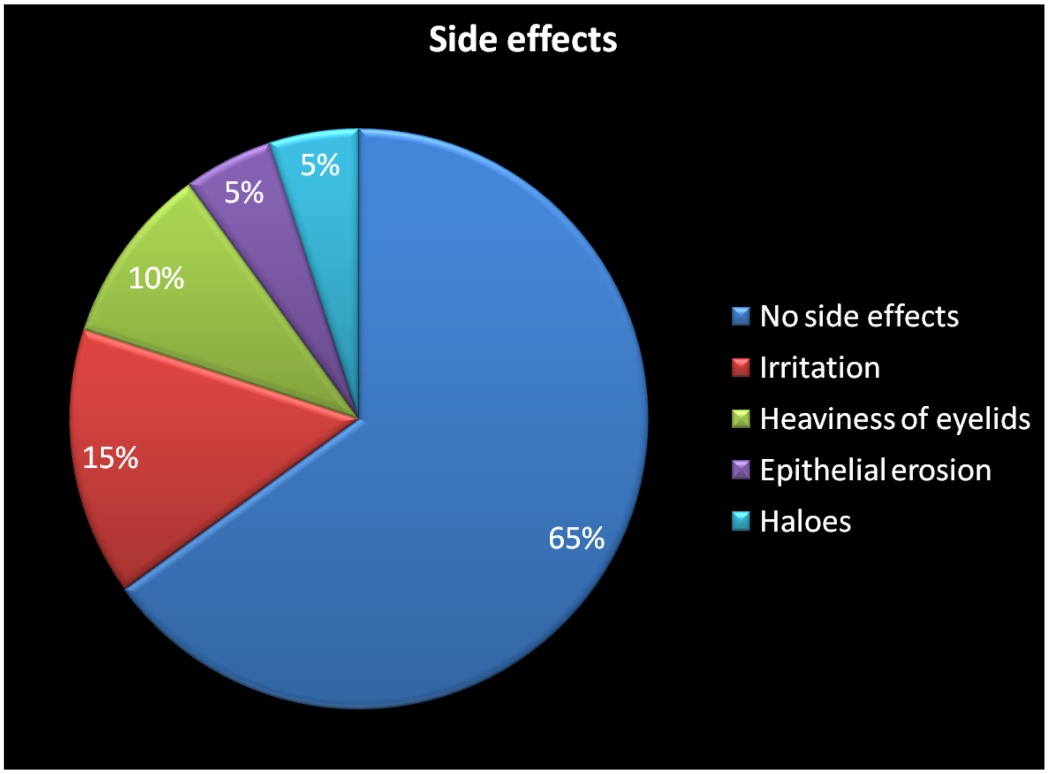


Fig 7. shows that 65% of the patients experienced no side effects. Ocular irritation, heaviness of eyelids, epithelial erosion and haloes were seen in 15%, 10%, 5% and 5% of the patients respectively.

FOLLOW UP

- 5 patients (SEQ -2.0D to -5.0D) were followed up weekly for 1 month.
- All 5 patients achieved the complete refractive correction at the end of 1 week.
- All of them reported an increase in the duration of daytime clear vision as the weeks progressed.
- Side effects like irritation and haloes resolved over one week.
- Topography showed consistent flattening of the central cornea.

ORTHOKERATOLOGY FOR KERATOCONUS PATIENTS

Aim

a) To assess the effectiveness of orthokeratology in the refractive correction of keratoconus patients

b) To evaluate the change in corneal topographic parameters in keratoconus patients fitted with day-wear orthokeratology contact lenses

Inclusion criteria

- Mild to moderate keratoconus
- No significant corneal thinning
- Patients who were not candidates for keratoplasty
- RGP lens wearers were asked to discontinue lens wear for 3 weeks before the ortho-k trial

Exclusion criteria

- Advanced keratoconus
- Significant corneal thinning
- Corneal hydrops and scarring
- Intolerance to RGP lenses

Materials and Methods

6 eyes of 4 patients with mild to moderate keratoconus were fitted with ortho-k lenses and the results were evaluated.

A slit lamp examination was performed to confirm the presence of keratoconus and to rule out significant corneal thinning/scarring.

Corneal topography was done to establish a diagnosis of keratoconus and also for the purpose of lens fitting.

The uncorrected and best corrected visual acuity were recorded.

The fitting was done according to flat K value and the target power.

The patients were asked to wear the lenses for 10 hours during the day and not at night.

They were reviewed the next day and thereafter every week for a period of 1 month.

At each visit, the visual acuity with the lenses on was measured. A slit lamp examination was performed and corneal topography was recorded after removing the contact lenses.

Observation and Analysis

Of the six keratoconic eyes fitted with orthokeratology contact lenses, two eyes showed an improvement of 2 lines of visual acuity on the Snellen's chart, one eye showed an improvement of 3 lines, one eye showed an improvement of 5 lines and two eyes had an improvement of 1 line of visual acuity on the Snellen's chart.

The mean improvement in visual acuity was 2.33 lines on the Snellen's chart.

The corneal topography measured before and after the ortho-k lens fitting did not show a significant change in the parameters.

RESULTS

- The mean refractive correction achieved after overnight orthokeratology was -2D.
- 50% of the eyes attained 1D to 2D correction and 35% eyes achieved 2D to 3D of myopia correction.
- 32.5% eyes showed a flattening of 1.5D to 2.0D in the central cornea and 22.5% showed flattening of 2D to 2.5D after a single OrthoK application.
- The corneal eccentricity values were indicative of a change in shape from prolate to oblate.
- SRI values increased after overnight orthokeratology but did not exceed the normal range and caused no significant impairment of vision
- SAI demonstrated a trend towards asphericity without significant visual impairment.
- 60% patients were able to maintain clear vision for 6 to 8 hours during the day.

- There were no significant side effects reported.

- In case of the keratoconus patients, a mean improvement of 2.33 lines of visual acuity on Snellen's chart was noted as compared to the best spectacle corrected visual acuity.

- Corneal topographic parameters did not show a significant change in keratoconus patients on a day wear ortho-k schedule.

DISCUSSION

Overnight orthokeratology has an important application in the treatment of myopia especially in the young patients.

It may have a role in retarding the progression of myopia and reducing the incidence of complications of pathological myopia.[54,55]

RGP lenses help retard axial elongation during the growth years.[56]

Orthokeratology gives better visual acuity as compared to spectacles in patients with keratoconus who can tolerate RGP contact lenses. It does not induce any topographic changes in keratoconic corneas when prescribed as day-wear lenses.

Advantages of orthokeratology[47]

- It provides good unaided vision for most of the day.
- It is a temporary and completely reversible procedure.
- It is a good nonsurgical alternative for children and patients who cannot undergo laser refractive surgery.
- It is not painful.

- The technique uses established contact lens procedures with minimal risk of problems.

- It is less expensive as compared to refractive surgery.

Disadvantages of orthokeratology[47]

- It can treat only low to medium degrees of myopia.

- Several visits are required over the first few months.

- For the best results, careful patient compliance is required.

CONCLUSION

Our study demonstrates that overnight orthokeratology is a safe and effective method for the correction of myopia. This is in accordance with certain studies in literature.[21,57,58,59] The central corneal flattening is consistent as evidenced by topography. The asphericity induced in the cornea during the treatment process does not significantly impair vision. Orthokeratology provides unaided clear vision for most part of the day in a majority of the patients. It is a viable nonsurgical alternative to refractive surgery.

Orthokeratology improves the visual acuity over and above the best spectacle corrected visual acuity in patients with keratoconus who can tolerate RGP contact lenses. These lenses, when given for day-wear, do not induce any topographic changes in patients with keratoconus.

Initiating orthokeratology at a younger age may have the beneficial effect of retarding the progression of myopia and significantly reducing the incidence of complications associated with pathological myopia.

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PROFORMA

Date: OP No:

Name: Age/Sex:

	Right eye	Left eye
Head posture		
Facial symmetry		
Extraocular movements		
Anterior segment		
Eyelids		
Conjunctiva		
Cornea		
Iris		
AC		
Pupil diameter		
Lens		
Schirmer's test		
Tear film break up time		
Fundus examination		

RIGHT EYE		LEFT EYE	
UCVA:		UCVA:	
BCVA:		BCVA:	
Topography:		**Topography:**	
Flat K:	E value:	Flat K:	E value:
Steep K:		Steep K:	
Base Curve:		Base Curve:	
OK lens:	Status	OK lens:	Status
1st fit:		1st fit:	
Vn with OK lens:		Vn with OK lens:	
<u>POK Day 1:</u>		<u>POK Day 1:</u>	
UCVA:		UCVA:	
BCVA:		BCVA:	
Flat K:	E value:	Flat K:	E value:
Steep K:		Steep K:	

	Right eye	Left eye
Lens centration		
Lens movement		

FOLLOW UP

RIGHT EYE		**LEFT EYE**	
POK Week 1:		POK Week 1:	
UCVA:		UCVA:	
BCVA:		BCVA:	
Flat K:		Flat K:	
Steep K:	E value:	Steep K:	E value:
POK Month 1:		POK Month 1:	
UCVA:		UCVA:	
BCVA:		BCVA:	
Flat K:		Flat K:	
Steep K:	E value:	Steep K:	E value:
POK Month 3:		POK Month 3:	
UCVA:		UCVA:	
BCVA:		BCVA:	
Flat K:		Flat K:	
Steep K:	E value:	Steep K:	E value:
POK Month 6:		POK Month 6:	
UCVA:		UCVA:	
BCVA:		BCVA:	
Flat K:		Flat K:	
Steep K:	E value:	Steep K:	E value:
POK Year 1:		POK Year 1:	
UCVA:		UCVA:	
BCVA:		BCVA:	
Flat K:		Flat K:	
Steep K:	E value:	Steep K:	E value:

KEY TO MASTER CHART

Pre OK	-	Pre orthokeratology
Steep K	-	Steeper axis
Flat K	-	Flatter axis
Cyl	-	Cylinder
E value	-	Corneal eccentricity value
Avg K	-	Average of the K values
SRI	-	Surface Regularity Index
SAI	-	Surface Asymmetry Index
UCVA	-	Uncorrected Visual Acuity
BCVA	-	Best Corrected Visual Acuity
POKD1	-	Post Orthokeratology (lens wear) Day 1
Vn	-	Vision
OK lens	-	Orthokeratology lens
DS	-	Dioptre sphere
DC	-	Dioptre cylinder

LIST OF SURGERIES PERFORMED

S. No.	Name	Age / Sex	OP / IP No.	Diagnosis	Surgery performed
1.	Thiruvaimozhi	75/F	407842	BE – MC	RE – ECCE with PCIOL
2.	Pushpa	60/F	411326	BE – MC	LE – ECCE with PCIOL
3.	Devi	65/F	411564	BE – PCC	LE – ECCE with PCIOL
4.	Govindasamy	62/M	412232	RE - MC LE – IMC	RE – ECCE with PCIOL
5.	Durairaj	80/M	413582	BE – MC	RE – ECCE with PCIOL
6.	Palanivel	24/M	1573	RE – Upper lid tear	RE – Upper lid tear suturing
7.	Sujatha	18/F	36891	RE – Lower lid chalazion	RE – Chalazion I and C
8.	Perumal	57/M	42675	Left sided Chronic dacryocystitis	Left sided DCT
9.	Vadivel	47/M	42445	RE – Pterygium	RE – Pterygium excision with conjunctival autograft
10.	Lakshmi	55/F	420098	BE – IMC	RE – SICS with PCIOL
11.	Venkatesh	64/M	420580	RE – PCC LE – Pseudophakia	RE – SICS with PCIOL

12.	Patabi	68/M	420720	BE – Nuclear cataract	RE – SICS with PCIOL
13.	Ponnusamy	61/M	421086	RE – Pseudophakia LE – PCC	LE – SICS with PCIOL
14.	Rani	68/F	421198	RE – IMC LE - Pseudophakia	RE – SICS with PCIOL
15.	Rangasamy	54/M	45653	Right sided Chronic dacryocystitis	Left sided DCT
16.	Rajesh	35/M	422671	RE – Fungal corneal ulcer	RE- TKP
17.	Subhadra	37/F	37658	RE – Pterygium	RE – Pterygium excision with conjunctival autograft
18.	Peter	53/M	1786	LE – Scleral tear with uveal tissue prolapse	LE - Scleral tear suturing
19.	Anandan	46/M	422702	LE – Non healing fungal corneal ulcer	LE – TKP
20.	Selvi	20/F	422783	LE – Perforated fungal corneal ulcer	LE – TKP
21.	Ganeshan	30/M	422852	RE – Non healing fungal corneal ulcer	RE – TKP
22.	Siva	32/M	2208	RE – Ruptured globe	RE – Corneo-scleral tear

					suturing
23.	Lakshmi M	63/F	423102	RE – PCC LE – Pseudophakia	RE – Phaco with PCIOL
24.	Ravannammal	73/F	423126	BE – PCC	RE – Phaco with PCIOL
25.	Parthiban	65/M	423227	RE – HMC LE – IMC	RE – SICS with PCIOL
26.	Parvathi	58/F	423265	BE – IMC	LE – Phaco with PCIOL
27.	Sushila	60/F	423311	RE – Pseudophakia LE – PCC	LE – Phaco with PCIOL
28.	Manikam	55/M	423388	BE- PCC	RE – Phaco with PCIOL
29.	Janaki	23/F	21486	LE – Upper lid mass [suspected lipoma]	LE – Excision biopsy of the upper lid mass
30.	Palayam	74/M	32561	Right sided lacrimal abscess	I and D of the lacrimal abscess
31.	Pavithra	24/F	43265	RE – Pterygium	RE – Pterygium excision with conjunctival autograft
32.	Shekhar	47/M	2436	LE – Ruptured globe	LE – Corneo-scleral tear suturing done

BE – Both Eyes

RE – Right Eye

LE – Left Eye

MC – Mature Cataract

IMC – Immature Cataract

HMC – Hyper Mature Cataract

PCC – Posterior Cortical Cataract

ECCE – Extra Capsular Cataract Extraction

SICS – Small Incision Cataract Surgery

PCIOL – Posterior Chamber Intraocular Lens

Phaco – Phacoemulsification

DCT - Dacryocystectomy

TKP – Therapeutic Keratoplasty

I and C – Incision and Curettage

I and D – Incision and Drainage

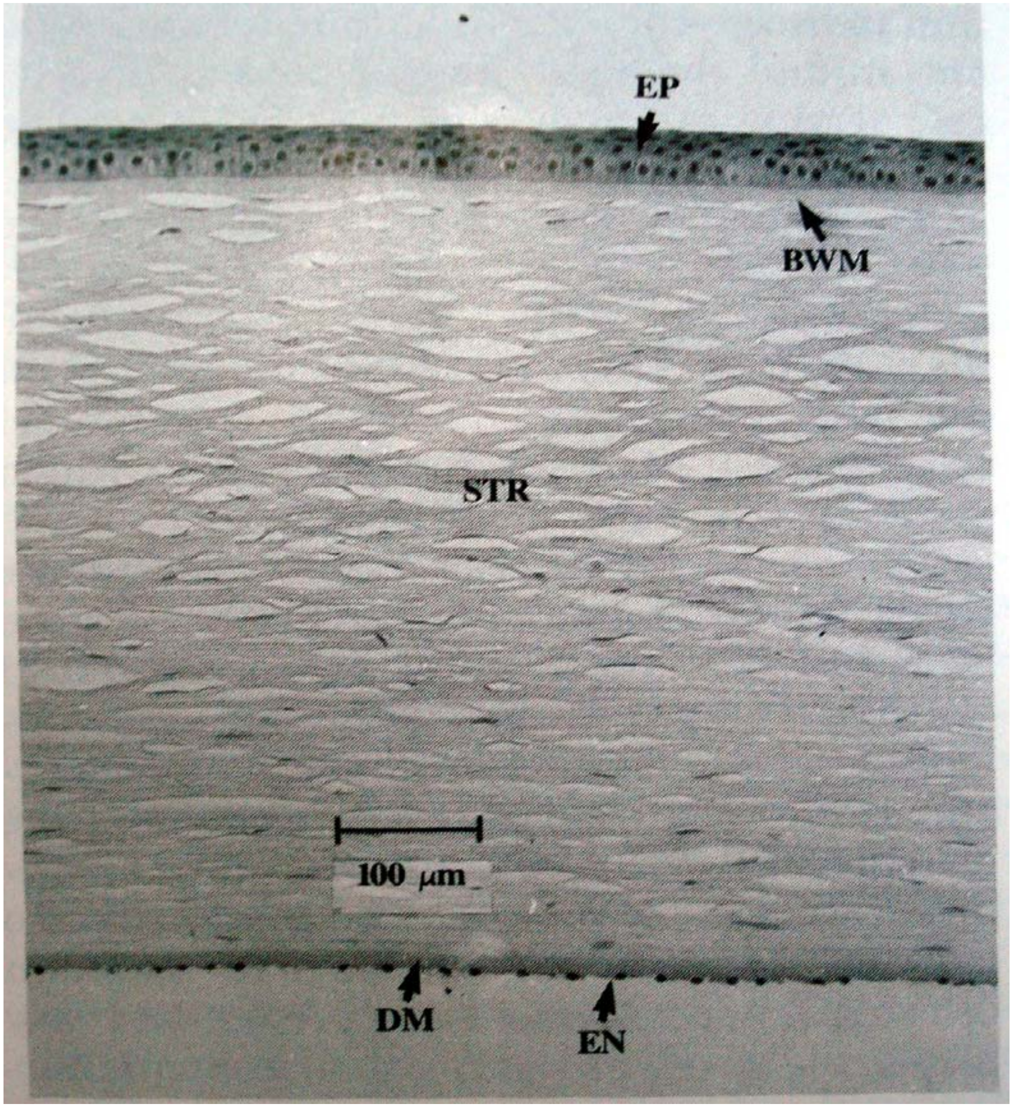

Fig 1. Photomicrograph of normal human cornea showing the stratified squamous epithelium (EP), Bowman's membrane (BWM), stroma (STR), Descemet's membrane (DM) and endothelium (EN) [37]

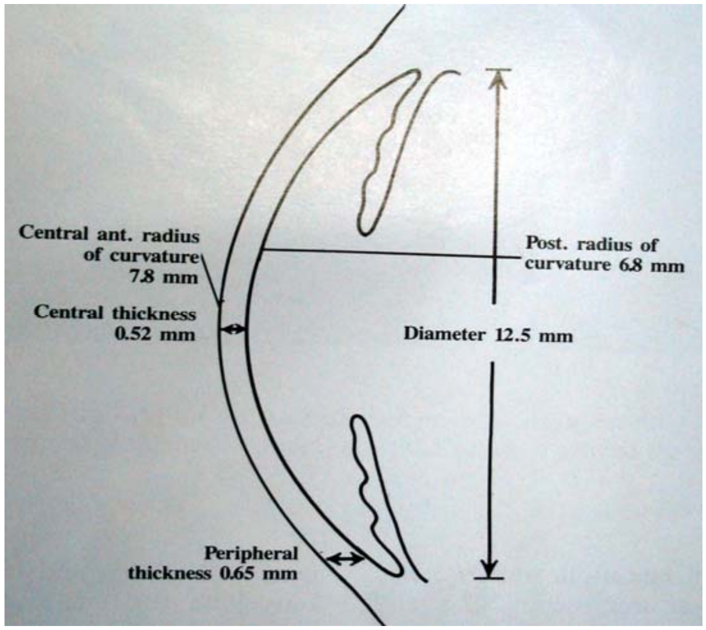

Fig 3. Corneal dimensions[37]

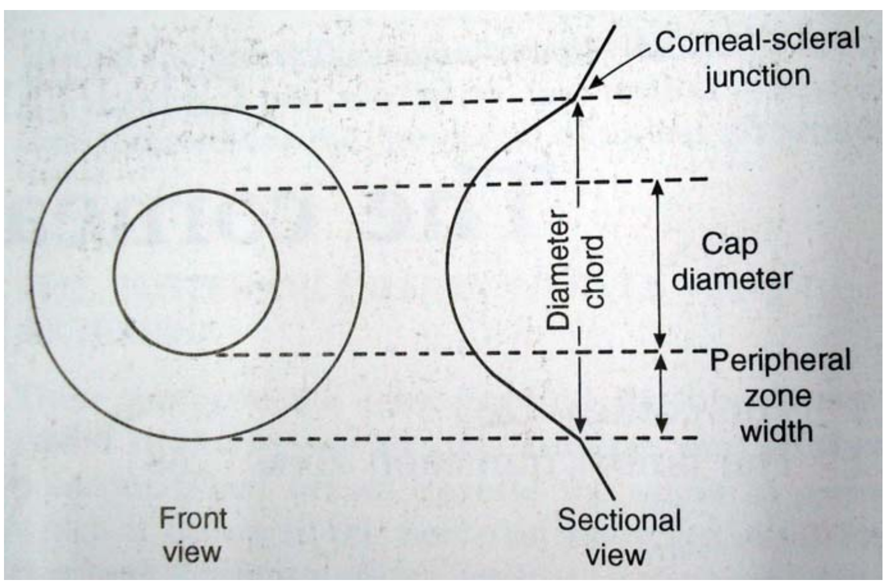

Fig 4. Corneal cap on topography

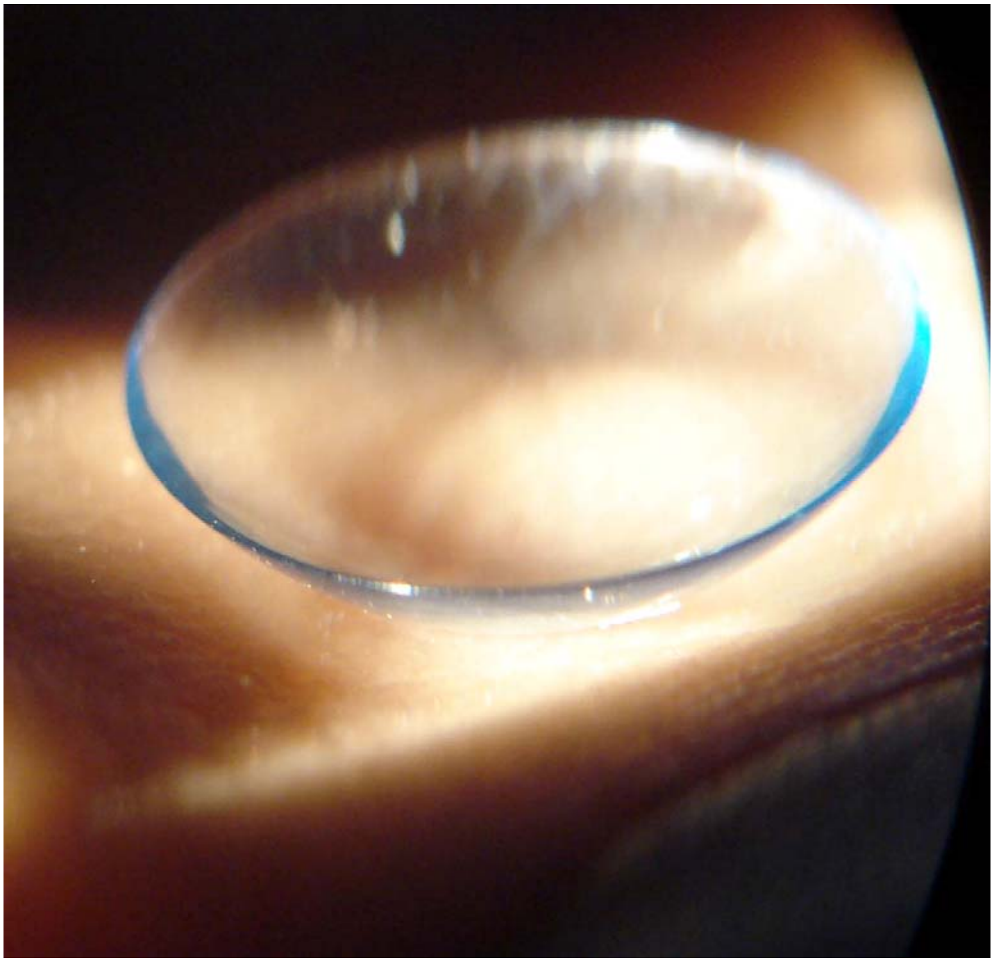

Fig 5. Clinical photograph showing an orthokeratology contact lens.

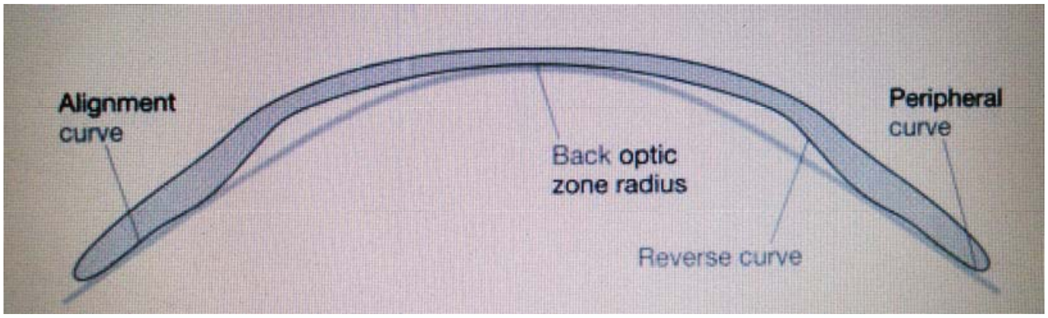

Fig 6. Four curve reverse geometry lens showing the base curve, reverse curve, alignment curve and peripheral curve.

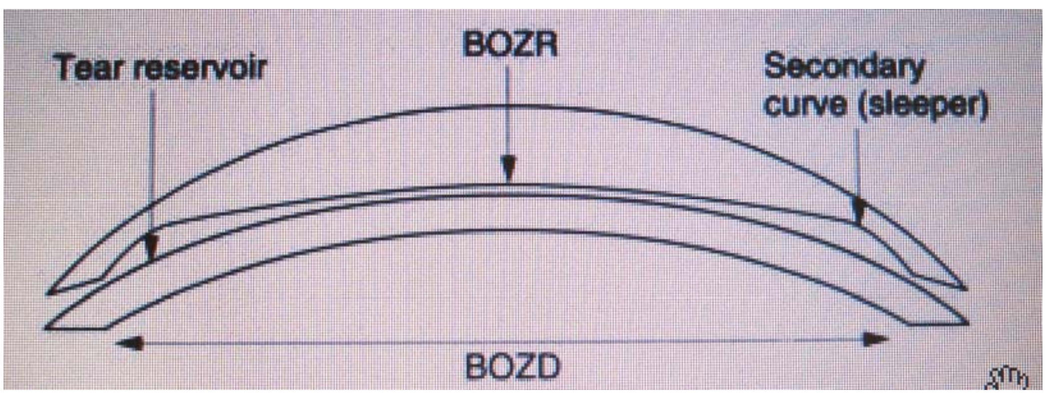

Fig 7. Diagram showing the BOZD (back optic zone diameter) and BOZR (back optic zone radius) of a reverse geometry lens.

C&E G P Specialists Advanced Corneal Reshaping Lenses
Inventory Lens Alignment Curves

1/1/2008

FLAT "K"	TARGET POWER -1.00		-1.50		-2.00		-2.50		-3.00		-3.50		-4.00		-4.50		-5.00		-5.50	
46.00	44.00	C5	43.50	E5	43.00	G5	42.50	I5	42.00	K5	41.50	M5	41.00	O5	40.50	Q5	40.00	S5	39.50	U5
AC	7.49		7.49		7.49		7.49		7.49		7.49		7.49		7.49		7.49		7.49	
45.50	43.50	C7	43.00	E7	42.50	G7	42.00	I7	41.50	K7	41.00	M7	40.50	O7	40.00	Q7	39.50	S7	39.00	U7
AC	7.56		7.56		7.56		7.56		7.56		7.56		7.56		7.56		7.56		7.56	
45.00	43.00	C9	42.50	E9	42.00	G9	41.50	I9	41.00	K9	40.50	M9	40.00	O9	39.50	Q9	39.00	S9	38.50	U9
AC	7.64		7.64		7.64		7.64		7.64		7.64		7.64		7.64		7.64		7.64	
44.50	42.50	C11	42.00	E11	41.50	G11	41.00	I11	40.50	K11	40.00	M11	39.50	O11	39.00	Q11	38.50	S11	38.00	U11
AC	7.72		7.72		7.72		7.72		7.72		7.72		7.72		7.72		7.72		7.72	
44.00	42.00	C13	41.50	E13	41.00	G13	40.50	I13	40.00	K13	39.50	M13	39.00	O13	38.50	Q13	38.00	S13	37.50	U13
AC	7.80		7.80		7.80		7.80		7.80		7.80		7.80		7.80		7.80		7.80	
43.50	41.50	C15	41.00	E15	40.50	G15	40.00	I15	39.50	K15	39.00	M15	38.50	O15	38.00	Q15	37.50	S15	37.00	U15
AC	7.88		7.88		7.88		7.88		7.88		7.88		7.88		7.88		7.88		7.88	
43.00	41.00	C17	40.50	E17	40.00	G17	39.50	I17	39.00	K17	38.50	M17	38.00	O17	37.50	Q17	37.00	S17	36.50	U17
AC	7.97		7.97		7.97		7.97		7.97		7.97		7.97		7.97		7.97		7.97	
42.50	40.50	C19	40.00	E19	39.50	G19	39.00	I19	38.50	K19	38.00	M19	37.50	O19	37.00	Q19	36.50	S19	36.00	U19
AC	8.05		8.05		8.05		8.05		8.05		8.05		8.05		8.05		8.05		8.05	
42.00	40.00	C21	39.50	E21	39.00	G21	38.50	I21	38.00	K21	37.50	M21	37.00	O21	36.50	Q21	36.00	S21	35.50	U21
AC	8.14		8.14		8.14		8.14		8.14		8.14		8.14		8.14		8.14		8.14	
41.50	39.50	C23	39.00	E23	38.50	G23	38.00	I23	37.50	K23	37.00	M23	36.50	O23	36.00	Q23	35.50	S23	35.00	U23
AC	8.23		8.23		8.23		8.23		8.23		8.23		8.23		89.23		8.23		8.23	
41.00	39.00	C25	38.50	E25	38.00	G25	37.50	I25	37.00	K25	36.50	M25	36.00	O25	35.50	Q25	35.00	S25	34.50	U25
AC	8.33		8.33		8.33		8.33		8.33		8.33		8.33		8.33		8.33		8.33	
40.50	38.50	C27	38.00	E27	37.50	G27	37.00	I27	36.50	K27	36.00	M27	35.50	O27	35.00	Q27	34.50	S27	34.00	U27
AC	8.42		8.42		8.42		8.42		8.42		8.42		8.42		8.42		8.42		8.42	
40.00	38.00	C29	37.50	E29	37.00	G29	36.50	I29	36.00	K29	35.50	M29	35.00	O29	34.50	Q29	34.00	S29	33.50	U29
AC	8.52		8.52		8.52		8.42		8.52		8.52		8.52		8.52		8.52		8.52	
39.50	37.50	C31	37.00	E31	36.50	G31	36.50	I31	35.50	K31	35.00	M31	34.50	O31	34.00	Q31	33.50	S31	33.00	U31
AC	8.62		8.62		8.62		8.52		8.62		8.62		8.62		8.62		8.62		8.62	

Fig 8. The nomogram showing the various ortho-k lenses in the inventory based on the target power and the flat K value

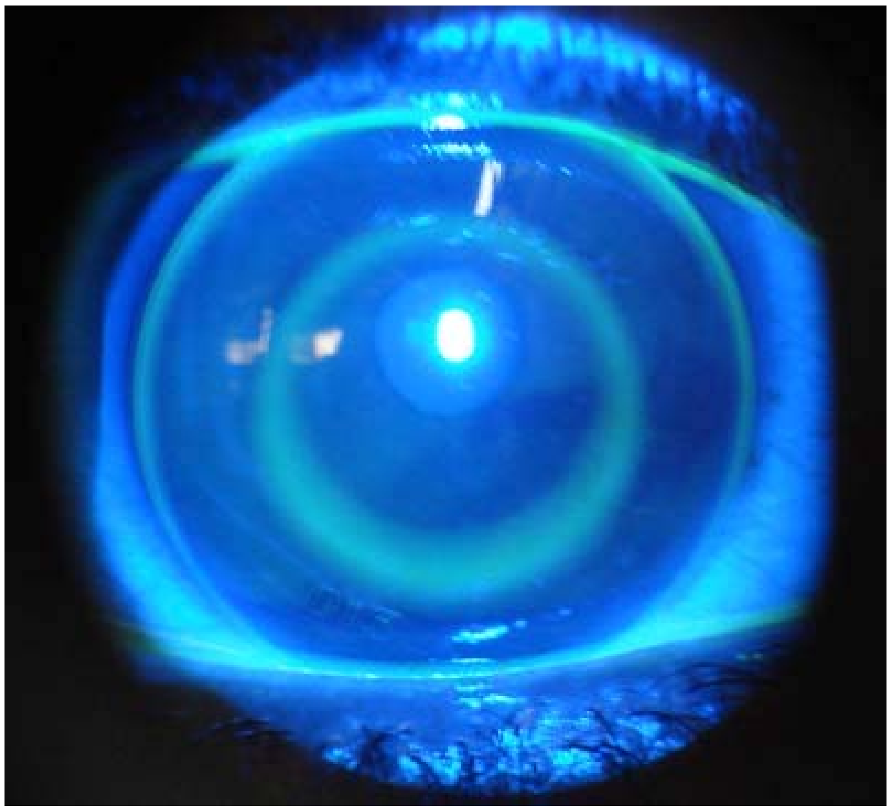

Fig 9. Slit lamp photograph showing the characteristics of an ideal fit of orthokeratology contact lens after staining with 2% Fluorescein dye

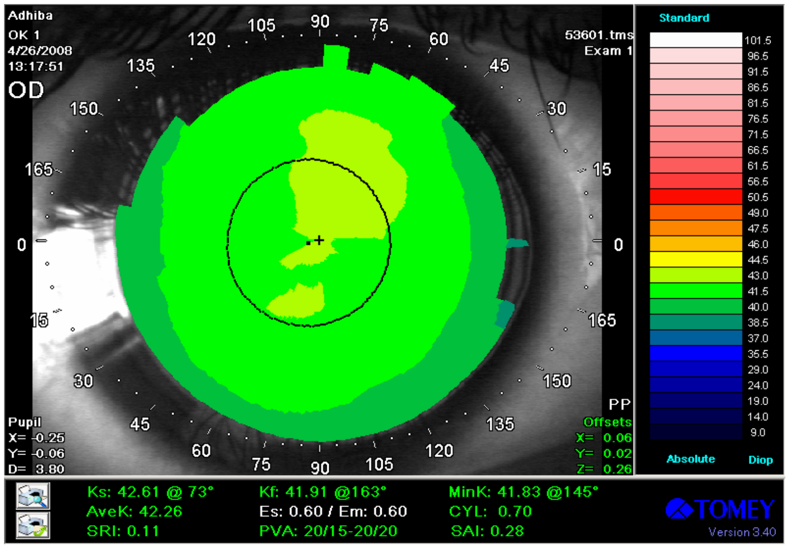

Fig 10a. Corneal topography picture before fitting orthokeratology lens.

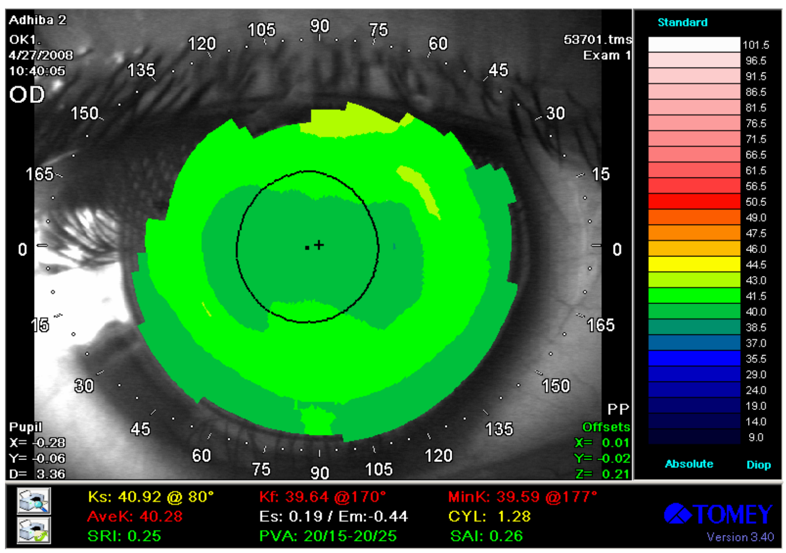

Fig 10b. Corneal topography picture taken after overnight ortho-k lens wear showing the flattening of the central cornea and a bull's eye pattern of centration.

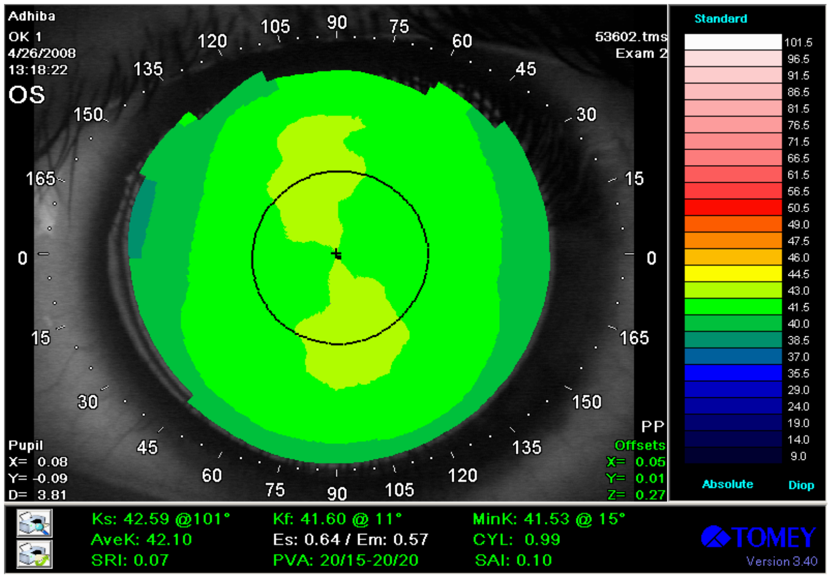

Fig 11a. Corneal topography picture before fitting orthokeratology lens.

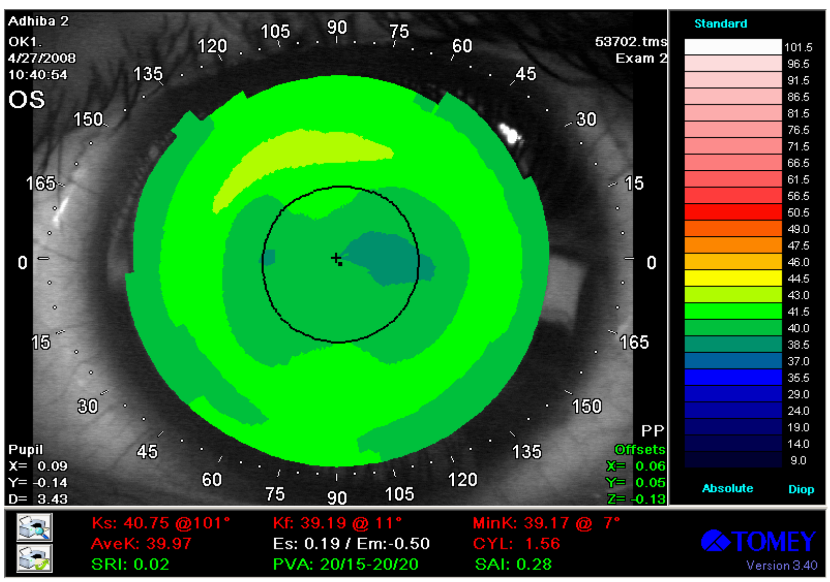

Fig 11b. Corneal topography picture taken after overnight ortho-k lens wear showing central corneal flattening.

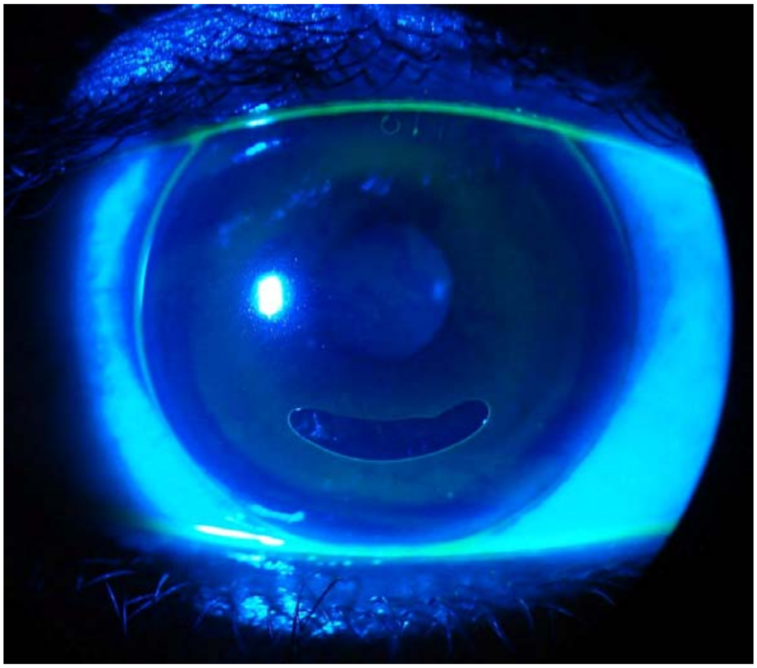

Fig. 12 Slit lamp photograph showing air bubble inferiorly under the contact lens

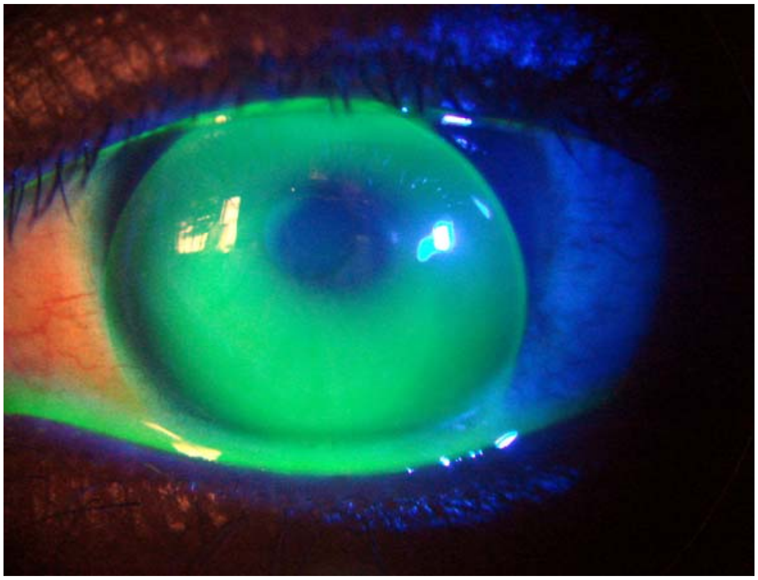

Fig. 13 Slit lamp photograph showing steep fit of the contact lens

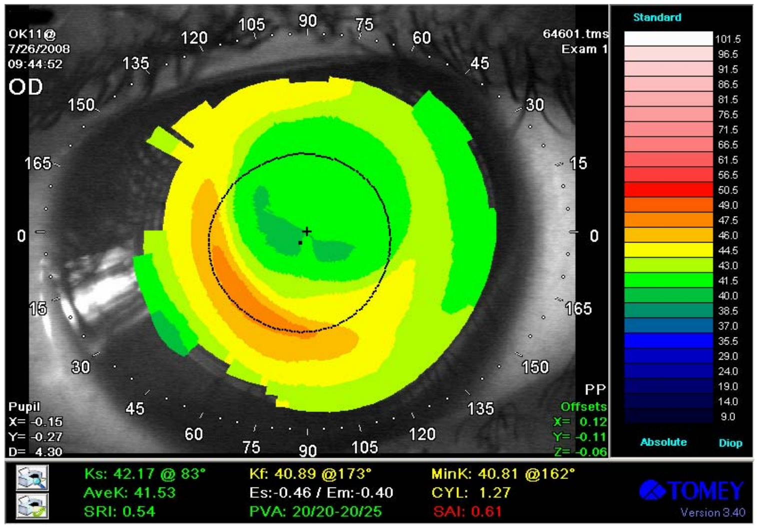

Fig. 14 Corneal topography picture showing eccentric flattening

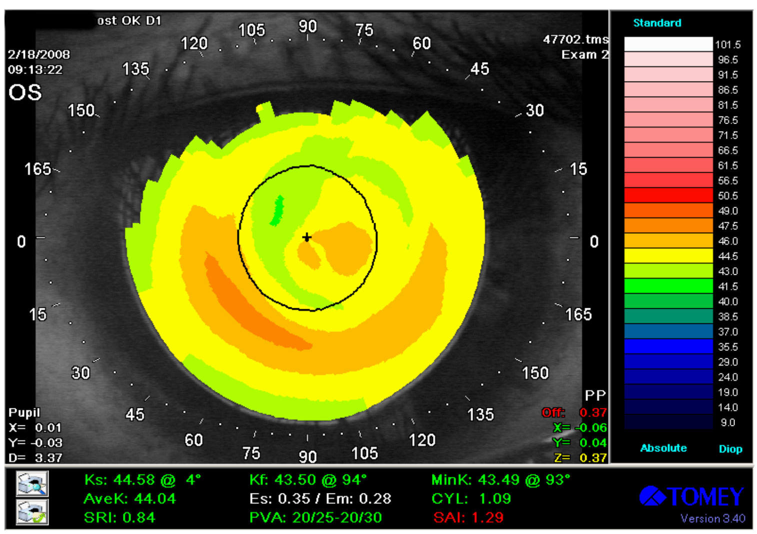

Fig. 15 Corneal topography picture showing smiley face pattern

		Right Eye							Left Eye						
No	**Name**	**Steep K**	**Flat K**	**Cyl**	**E value**	**Avg K**	**SRI**	**SAI**	**Steep K**	**Flat K**	**Cyl**	**E value**	**Avg K**	**SRI**	**SAI**
1	Amudha PreOK	44.34 @ 89	43.44 @ 179	0.9	0.81	43.89	0.16	0.21	44.72 @ 100	43.54 @ 10	1.18	0.77	44.13	0.08	0.18
	POKD1	43.47 @ 94	42.54 @ 4	0.93	0.37	43.01	0.24	0.33	42.96 @ 101	41.77 @ 11	1.19	-0.18	42.36	0.32	0.36
2	Bharatkumar	44.25 @ 96	43.88 @ 6	0.38	0.66	44.06	0.16	0.22	44.59 @ 96	43.85 @ 6	0.74	0.57	44.22	0.23	0.78
	POKD1	42.90 @ 11	41.50 @ 101	1.39	-0.22	42.2	0.66	0.55	42.88 @ 69	42.62 @ 159	0.27	-0.03	42.75	0.39	0.93
3	Janani	43.17 @ 82	42.56 @ 172	0.61	0.42	42.87	0.12	0.23	43.61 @ 101	42.91 @ 11	0.7	0.31	43.26	0.42	0.2
	POKD1	40.41 @ 107	39.74 @ 17	0.67	-0.55	40.07	0.47	0.63	42.01 @ 94	41.24 @ 4	0.77	-0.33	41.63	0.5	0.97
4	Gayathri	45.69 @103	44.61 @ 13	1.08	0.54	45.15	0.03	0.38	45.68 @ 89	45.02 @ 179	0.65	0.56	45.35	0.07	0.19
	POKD1	44.22 @101	42.82 @ 11	1.4	-0.46	43.52	0.02	0.27	43.81 @ 68	43.09 @ 158	0.72	-0.47	43.45	0.18	0.38
5	Sathyendran	44.23 @ 155	43.70 @ 65	0.53	0.54	43.96	0.07	0.1	43.8	43.8	0	0.55	43.8	0.07	0.12
	POKD1	42.52 @ 135	42.12 @ 45	0.4	-0.31	42.32	0.06	0.17	41.89 @ 55	41.68 @ 145	0.21	-0.53	41.79	0.06	0.21
6	Thirumalaiselv	45.16 @ 37	44.81 @ 127	0.36	0.58	44.99	0.16	0.22	45.64 @ 4	45.05 @ 94	0.59	0.59	45.35	0	0.24
	POKD1	42.98 @ 167	42.17 @ 77	0.81	-0.49	42.57	0.56	0.47	44.58 @ 4	43.50 @ 94	1.09	0.48	44.04	0.84	1.29
7	Adhiba	42.61 @ 73	41.91 @ 163	0.7	0.6	42.26	0.11	0.28	42.59 @ 101	41.60 @ 11	0.99	0.57	42.1	0.07	0.1
	POKD1	40.92 @ 80	39.64 @ 170	1.28	-0.44	40.28	0.25	0.26	40.75 @ 101	39.19 @ 11	1.56	-0.05	39.97	0.02	0.28
8	Prabuvenkatesh	42.50 @138	41.69 @ 48	0.81	0.53	42.09	0.1	0.38	42.56 @ 53	42.06 @ 143	0.5	0.59	42.31	0.04	0.28
	POKD1	40.97 @ 142	40.38 @ 52	0.59	-0.17	40.67	0.48	0.48	40.93	40.93	0	-0.28	40.93	0.06	0.26
9	Shreeyeh	42.58 @ 87	41.63 @ 177	0.95	0.9	42.11	0.13	0.22	43.16 @ 100	42.02 @ 10	1.14	0.68	42.59	0.03	0.29
	POKD1	42.29 @ 90	41.67 @ 180	0.62	0.32	41.98	0.61	0.31	42.11 @ 108	41.09 @ 18	1.02	-0.36	41.6	0.56	0.5
10	Meenadevi	44.45 @ 101	43.85 @ 11	0.61	0.46	44.15	0.27	0.3	44.81 @ 83	44.01 @ 173	0.79	0.46	44.41	0.11	0.25
	POKD1	42.03 @ 98	41.24 @ 8	0.79	-0.62	41.64	0.55	1.67	42.67 @ 97	41.37 @ 7	1.3	-0.45	42.02	0.61	1.75
11	Nithin	44.69 @ 89	43.96 @ 179	0.73	0.55	44.33	0.2	0.34	45.13 @ 101	44.33 @ 11	0.79	0.58	44.73	0.01	0.21
	POKD1	44.00 @ 94	42.60 @ 4	1.41	-0.07	43.3	0.04	0.39	43.78 @ 82	42.75 @ 172	1.04	-0.04	43.26	0.07	0.17
12	Bama	44.62 @ 96	44.25 @ 6	0.36	0.45	44.43	0.06	0.21	45.46 @ 83	45.24 @ 173	0.22	0.48	45.35	0.67	0.33
	POKD1	44.30 @ 80	43.98 @ 170	0.32	0.3	44.14	0.32	0.43	44.90 @ 96	44.17 @ 6	0.73	-0.23	44.53	0.69	0.81

		Right Eye							Left Eye						
No	**Name**	**Steep K**	**Flat K**	**Cyl**	**E value**	**Avg K**	**SRI**	**SAI**	**Steep K**	**Flat K**	**Cyl**	**E value**	**Avg K**	**SRI**	**SAI**
13	Anusha	45.29 @ 3	42.56 @ 93	2.73	0.84	43.92	0.88	0.35	43.27 @ 80	42.40 @ 170	0.87	0.74	42.83	0.06	0.12
	POKD1	42.49 @ 101	41.88 @ 11	0.61	0.45	42.19	0.47	0.56	42.79 @ 73	42.07 @ 163	0.73	0.5	42.43	0.28	0.57
14	Shakthi	44.08 @ 14	43.18 @ 104	0.9	0.64	43.63	0.24	0.4	43.18 @ 93	42.13 @ 3	1.05	0.72	42.65	0.18	0.34
		42.16 @ 20	42.02 @ 110	0.14	-0.29	42.09	0.51	0.56	40.97 @ 106	40.23 @ 16	0.74	-0.3	40.6	0.21	0.52
15	Sujatha	44.10 @ 97	43.60 @ 7	0.5	0.57	43.85	0.08	0.24	43.00 @ 1	42.40 @ 91	0.6	0.44	42.7	0.04	0.38
		43.35 @ 100	42.75 @ 10	0.6	-0.12	43.05	0.12	0.42	42.4 @ 8	41.54 @ 98	0.86	-0.26	41.97	0.11	0.49
16	Manohar	42.02 @ 165	41.22 @ 75	0.8	0.73	41.62	0.3	0.32	42.35 @ 70	41.65 @ 160	0.7	0.64	42	0.13	0.21
		40.02 @ 70	38.82 @ 160	1.2	-0.24	39.42	0.41	0.46	40.04 @ 85	39.00 @ 175	1.04	-0.38	39.52	0.2	0.38
17	Pavithra	42.00 @ 105	41.50 @ 15	0.5	0.48	41.75	0.14	0.19	43.10 @ 10	42.33 @ 100	0.77	0.55	42.71	0.28	0.4
		40.12 @ 96	39.22 @ 6	0.9	-0.3	39.67	0.48	0.24	40.67 @ 80	39.79 @ 170	0.88	-0.22	40.23	0.41	0.54
18	Natarajan	44.70 @ 112	44.30 @ 22	0.4	0.59	44.5	0.22	0.2	43.88 @ 15	43.48 @ 105	0.4	0.48	43.68	0.07	0.13
		43.07 @ 95	42.27 @ 5	0.8	-0.21	42.67	0.6	0.36	42.49 @ 10	41.59 @ 100	0.9	-0.38	42.04	0.13	0.28
19	Suchithra	41.90 @ 96	41.40 @ 6	0.5	0.44	41.65	0.4	0.14	41.88 @ 4	41.20 @ 94	0.68	0.52	41.54	0.04	0.24
		40.18 @ 25	39.58 @ 115	0.6	-0.28	39.88	0.2	0.26	40.42 @ 15	39.34 @ 105	1.08	-0.22	39.88	0.09	0.38
20	Nandini	42.65 @ 30	42.15 @ 120	0.5	0.5	42.4	0.05	0.24	42.77 @ 120	42.37 @ 30	0.4	0.64	42.57	0.3	0.1
		41.31 @ 45	40.31 @ 135	1	-0.36	40.81	0.15	0.5	40.59 @ 104	39.79 @ 14	0.8	-0.18	40.19	0.36	0.18

		Right Eye		Left Eye	
No	Name	PreOK	POKD1	PreOK	POKD1
1	Amudha UCVA	6/12	6/6	6/12	6/6
	BCVA	-1.25DS/-0.25DC 6/6		-1.75DS 6/6	
	Vn with OK lens	C17 6/6		E17 6/6	
	Correction		-1.25DS/-0.25DC		-1.75DS
2	Bharatkumar UCVA	6/36p	6/18p	6/36P	6/18P
	BCVA	-3.00DS/-0.50DC 6/6	-1.25DS/-0.50DC 180 6/6	-3.00DS/-0.50DC 6/6	-1.00DS/-0.50DC 6/6
	Vn with OK lens	I17 6/9		K17 6/9	
	Correction		-1.75DS		-2.00DS
3	Janani UCVA	3/60	6/36	3/60	6/36p
	BCVA	-6.50DS 6/6	-3.25DS 6/6	-7.00DS 6/6p	-5.00DS 6/6p
	Vn with OK lens	U17 6/18 -1.5DS 6/6		U19 6/18 -1.25DS6/6p	
	Correction		-3.25DS		-2.00DS
4	Gayathri UCVA	1/60	6/60	2/60	6/36
	BCVA	-10.00DS 6/9p	-7.50DS -0.50DC 170	-7.50DS 6/9p	-6.0DS -0.50DC 10 6/9
	Vn with OK lens	U11 6/36 -4.00DS6/9p		U9 6/24p -2.00DS 6/9	
	Correction		-2.50DS		-1.50DS
5	Sathyendran UCVA	6/24p	6/9	6/36p	6/9
	BCVA	-2.00DS 6/6	-0.50DS 6/6	-2.00DS 6/6	-0.50DS 6/6
	Vn with OK lens	G15 6/9		G13 6/9	
	Correction		-1.50DS		-1.50DS
6	Thirumalaiselv UCVA	5/60	6/12p	5/60	6/36
	BCVA	-5.75DS -0.50DC 90 6/6	-1.70DS -0.50DC 90 6/6	-5.50DS -0.50DC 90 6/9	-2.25DS -0.50DC 90 6/9
	Vn with OK lens	S11 6/12		Q11 6/9	
	Correction		-4.00DS		-2.25DS
7	Adhiba UCVA	6/60	6/6p	6/60	6/6p
	BCVA	-2.50DS -0.50DC 150 6/6		-2.50DS -0.75DC 15 6/6	
	Vn with OK lens	I23 6/6p		I23 6/6p	
	Correction		-2.50DS -0.50DC		-2.50DS -0.75DC
8	Prabuvenkatesh UCVA	6/36	6/6	6/36	6/6

		Right Eye		Left Eye	
No	**Name**	**PreOK**	**POKD1**	**PreOK**	**POKD1**
	BCVA	-1.75DS 6/6		-1.75DS 6/6	
	Vn with OK lens	G21 6/6		E21 6/6	
	Correction		-1.75DS		-1.75DS
9	Shreeyeh UCVA	5/60	6/36	5/60	6/12
	BCVA	-1.75DS -0.50DC 180 6/6	-1.00DS -0.50DC 180 6/6	-1.75DS -0.75DC 180 6/6	-1.00DS -0.25DC 180 6/6
	Vn with OK lens	E25 6/6	With 2nd fit G21 6/6	C25 6/6	With 2nd fit E25 6/6
	Correction		-0.75DS		-0.75DS -0.50DC
10	Meenadevi UCVA	3/60	6/9	3/60	6/9
	BCVA	-4.25DS 6/6	-1.50DS 6/6	-4.50DS 6/6	-1.00DC 180 6/6
	Vn with OK lens	O13 6/9		Q13 6/9	
	Correction		-2.75DS		-3.50DDS
11	Nithin UCVA	6/60	6/12	6/60	6/12
	BCVA	-3.25DS -0.50DC 145 6/6	-1.00DS 6/6	-3.25DS 6/6	-1.00DS 6/6
	Vn with OK lens	M13 6/9		K13 6/9	
	Correction		-2.25DS -0.50DC		-2.25DS
12	Bama UCVA	5/60	6/36	5/60	6/18
	BCVA	-4.00DS 6/6	-2.50DS 6/6	-3.50DS 6/6	-2.00DS 6/6
	Vn with OK lens	O13 6/6		O9 6/6	
	Correction		-1.50DS		-1.50DS
13	Anusha UCVA	6/60	6/36p	6/60	6/9
	BCVA	-2.50DS -0.25DC 25 6/6	-2.00DS 6/6	-3.00DS -0.50DC 157 6/6	-1.00DS 6/6
	Vn with OK lens	I17 6/18		K17 6/6p	
	Correction		-0.50DS -0.25DC		-2.00DS -0.50DC
14	Shakthi UCVA	6/60	6/12	5/60	6/9p
	BCVA	-2.75DS 6/6	-0.50DS 6/6	-3.00DS 6/6	-0.50DS 6/6
	Vn with OK lens	K17 6/9		K21 6/9	
	Correction		-2.25DS		-2.50DS
15	Sujatha UCVA	4/60	6/12	4/60	6/12
	BCVA	-4.00DS 6/6	-2.25DS 6/6	-4.00DS 6/6	-2.00DS 6/6

		Right Eye		Left Eye	
No	**Name**	**PreOK**	**POKD1**	**PreOK**	**POKD1**
	Vn with OK lens	O15 6/9p		019 6/9p	
	Correction		-1.75DS		-2.00DS
16	Manohar UCVA	6/60	6/6p	6/60	6/6p
	BCVA	-3.50DS -0.50DC 70 6/9	-1.00DS -0.50DC 70	-3.25DS -0.50DC 160 6/6	-1.00DS -0.50DC 160 6/6
	Vn with OK lens	M25 6/6p		M23 6/6p	
	Correction		-2.50DS		-2.25DS
17	Pavithra UCVA	6/24	6/6	6/24	6/6
	BCVA	-1.25DS 6/6	6/6	-1.50DS 6/6	6/6
	Vn with OK lens	C23 6/6		E21 6/6	
	Correction		-1.25DS		-1.50DS
18	Natarajan UCVA	5/60	6/9	5/60	6/9
	BCVA	-3.75DS 6/6	-0.75DS 6/6	-3.75DS 6/6	-0.75DS 6/6
	Vn with OK lens	O13 6/6		O15 6/6p	
	Correction		-3.00DS		-3.00DS
19	Suchithra UCVA	6/18	6/6	6/12	6/6
	BCVA	-1.50DS 6/6	6/6	-1.25DS 6/6	6/6
	Vn with OK lens	E25 6/6		C25 6/6	
	Correction		-1.50DS		-1.25DS
20	Nandini UCVA	6/24p	6/9	6/24	6/9
	BCVA	-2.50DS 6/6	-0.50DS 6/6	-2.00DS 6/6	-0.25DS 6/6p
	Vn with OK lens	I21 6/6		G21 6/6p	
	Correction		-2.00DS		-1.75DS