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Modern Orthokeratology- A Review

AtanuMajumdar
Department Of Ophthalmology Ghatsila, Jharkhand, India
Correspondance: AtanuMajumdar

Abstract: *Modern Orthokaratology (Ortho-k) using reverse geometry lens design is being widely used for temporary myopia reduction world wide. Myopia is a common ocular disorder, and progression of myopia in children is of increasing concern. Modern overnight Orthokeratology (Ortho-k) is effective for myopia reduction and has been claimed to be effective in slowing the progression of myopia (myopia control) in children, although scientific evidence for this has been lacking.*
Keywords: *Aberrations, Myopia control, Ocular disorder, Orthokeratology, Reverse geometry.*

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I. Background

Ortho-k treatment involves the use of rigid contact lenses to change the curvature of the cornea, results in a movement in refractive error towards plano [1,2]. It is believed that, the concept of Ortho-k came from ancient China, where small weights were used on eyelids to reduce myopia.

George Jessen [3] in 1962, developed the modern day Orthokeratology. Jessen used PMMA contact lenses which were flatter than the corneal curvature to flatten the cornea to reduce myopia. Clear unaided vision was achieved for few hours if the lenses were wore during the day and removed during afternoon.

During last two decades Ortho-k has become very popular which entails flattening the anterior corneal surface in an effort to adjust the eye's refractive power.

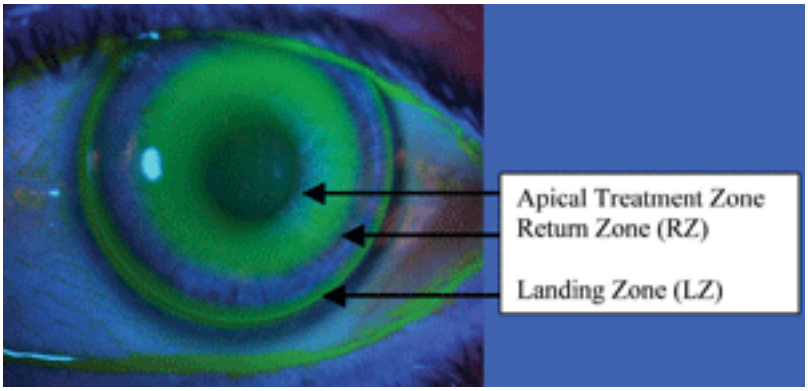


Image 1. The optimal fit and zone alignment of an Ortho-k lens.

Cornea:

Ortho-k causes flattening of the cornea to reduce the overall refractive power of the eye. The corneal structural changes occur due to mid-peripheral thickening and a central thinning [6].

Structural changes of the cornea are observed after at least 15 minutes of lens wear [8]. After 30 minutes the corneal changes are dependent on the refractive target of the custom made Orthokeratology lens. Structural change of the epithelium is responsible for the corneal reshaping. Some studies have also shown stromal change [7,10]. Dk/t (Oxygen transmissibility) of the lens material may also be a major reason for this [12].

The corneal epithelium cells change in both shape and size rather than causing cell layer alternation.

- The epithelium cells of the central cornea are compressed and flattened but there is no loss or migration of the cells.
- These mid-peripheral epithelial cells are larger and more oval. The thickered mid-peripheral cornea maintains normal cell layers; but there is a delayed surface cell exfoliation.

Fluorophotometry has been used to show that the permeability of the cornea is not compromised by using Ortho-k lenses [15]. The speed of effect and recovery (after removal of the lenses) from Ortho-k varies from patient to

patient as is dependent on corneal resistance. A lower resistance allows a faster response and a faster recovery.

Early Myopia Development And Progression:
Researchers from the Orinda Longitudinal study of myopia (OLSM) in 1989, observed the relation between normal eye growth and the development of myopia in school age children [4,5].
The researchers also investigated accommodative function, peripheral refractive error, intra ocular pressure, genetic/anatomical similarities with parents, refractive error profiles of other ethnic groups and overall DNA based studies on the prevalence of familial trends in myopia.

OSLM researchers found that refractive errors decreased towards emmetropia at an average of +0.73 D at age 6 years to an average of +0.50D by age 12 years [4]. Furthermore, from ages 6-12 years, the vitreous chamber elongated by approximately 0.52mm and the crystalline lens power decreased by approximately 1.35 D.
Excessive near point work and even prolonged dark exposure appears to strongly influence myopia progression [9]. Increased period of continuous reading and studying in poor lighting conditions are explained as it reason mostly in children.
Approximately 70% to 90% of individuals in Asian countries are near sighted [12].

Methods For Myopia Control:
Firstly, it must be assured that the child is not going to be blind, after that corrective eyewear should be suggested for best possible visual function and performance. Evidence based medicines should be summarized along with the methods for controlling myopia progression.
Confirmatory tests are required prior to detailed planning and discussion. These includes examinations such as Cycloplegic evaluation, accommodative response and lag, phoria, accommodative convergence/accommodation ratio, intraocular pressure, corneal topography and possibly wave front aberrometry[1,2].

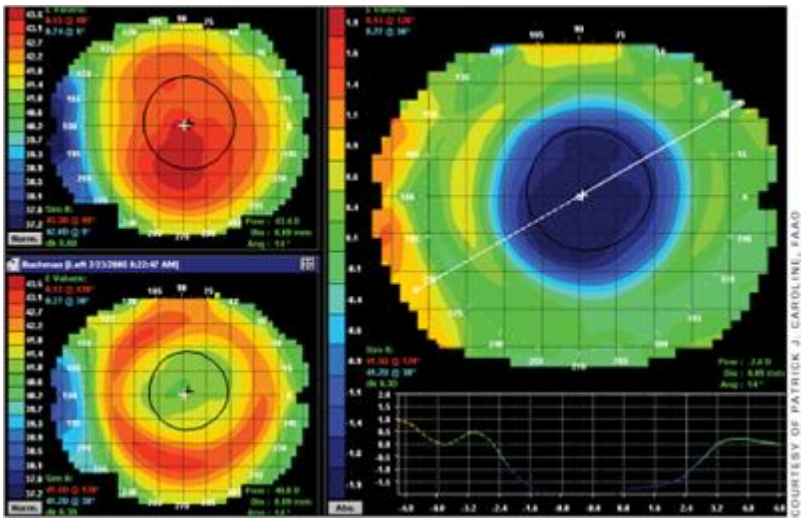


Image 2. The oblate corneal shape produced by Orthokeratology

Various Ways For Myopia Control:
- Single-vision eyeglasses
- Bifocals or separate reading prescription
- Progressive addition lenses
- Soft contact lenses (daily disposable, HEMA or siliconhydrogel)
- Rigid gas-permeable contact lenses (standard fit)
- Soft or rigid bifocal or multifocal contact lenses
- Orthokeratology lenses
- Pharmaceutical agents (atropine, pirenzepine, 7- methylxanthine)
- Acupunture
- Refractive Surgery (as a potential treatment option in adulthood
- Vision therapy

1. Myopia Control With Contact Lenses

Anatomical Influences On Refractive State

Myopia can be controlled with the help of Contact lenses which cause following anatomical influences on refractive state.

- Anterior corneal curvature
- Posterior corneal curvature
- Corneal thickness
- Refractive index
- Anterior chamber depth
- Axial length of eye
- Accommodation and convergence
- Choroidal, retinal and Vitreal pressure

Eye care practitioners, use contact lenses to slow or stabilized myopia progression. However, opinion on the effectiveness of this treatment vary widely [13].

In 1990, Russian researchers published results from a five-year longitudinal study, where the refraction remained unchanged in 73.2% patients who wore contact lenses [15].The authors suggested that he contact lenses stabilized the patient's accommodative abilities, which improved visual quality [15].

Silicon gas permeable lenses also have been used for controlling myopia.

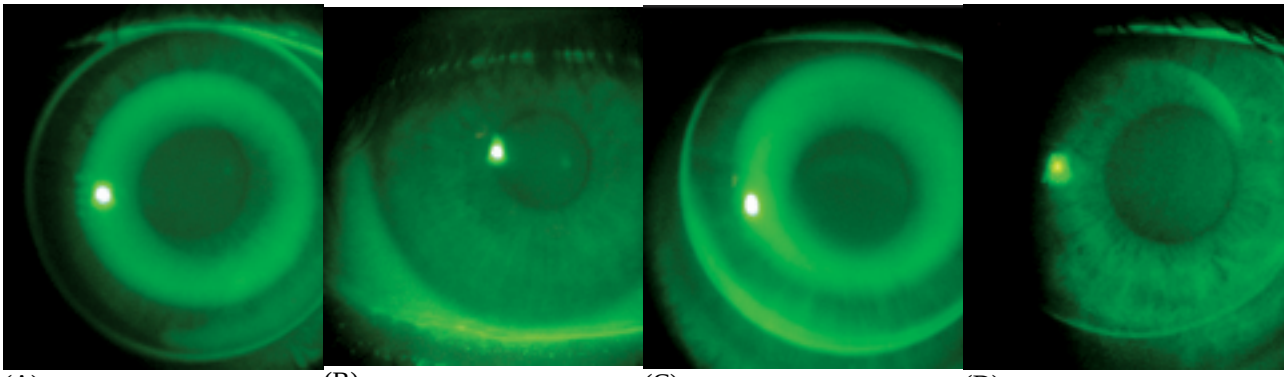
According to a study, the patients who wore daily silicon gas permeable lenses exhibited an increase in myopia of 0.28 D over a two year period, compared to 0.80 D in patients who wore spectacles [16].

2. Other Treatment Options:

- Topical atropine 1%, a non selective muscarinic antagonist, can be used to reduce myopia and ocular axial elongation progression in children [17].
- In a similar study, pirenzepine gel, cyclopentolate eye drops or atropine eye drops reduced myopia progression in children after 1 year then on children receiving a placebo [18].
- Acupunture has gained much importance as an alternative therapy for progressive myopia. It includes, the stimulation of strategic anatomical points by various methods including needle insertion and acupressure [22].
- Acupunture needles are inserted in specific auricular areas relative muscles spasms around the eye and improve ocular blood flow.

3. Ortho-k For Myopia Control

- Eyes with axial myopia are relatively more polate shaped than are emmetropic or hyperopic eyes; they exhibit relative peripheral hyperopia in the horizontal meridian compared with the fovea [27,28]. Ortho-k reduces myopia in the central 20 to 25 degree field [29,30] and causes a contrasting relative myopia shift in the peripheral field [28-30].
- In 2004, the results of the first report of COOKI (Children Overnight Ortho-k Investigation) pilot study determined that overnight Ortho-k was both a safe and effective method for myopia progression [19].
- In 2005 data from LORIC study (LongitudinalOrthokeratology Research In Children) suggested Ortho-k effectively can control childhood myopia [30]. However, the researches also found anatomical variations among children reduce the clinical ability to accurately predict final visual outcome, before starting the Ortho-k therapy [30].
- The 2 years CRAYON study, determined that patients who were fitted with Ortho-k lenses had significantly less annual change in axial length and vitreous chamber depth than patients fitted with soft contact lenses [22].
- In a study, the mean apical topographic power change was 1.11 D with slight corneal steepening in both meridians as well as 0.23mm of corneal flattening in the horizontal meridian and 0.27mm of corneal flattening in the vertical meridian [23]. Additionally, corneal eccentricity decreased by an average of 0.65e [24]. These results suggests that Ortho-k may be suitable for patients with low myopia.



(A) (B) (C) (D)

Image 3.A) Optimally centered fit of an Ortho-k lens. B) Cornea following optimally centered lens removal. Note virtually no trace of an impression ring. C) Superior-nasal decentered fit of an Ortho-k lens. D) Impression ring following decentered lens removal.

Quality Of Vision:

Generally Ortho-k gives satisfactory result. In a study patient's aging 21-37 years old was treated with Ortho-k were not troubled by vision clarity, near vision, distant vision, diurnal fluctuations or activities limitations [19]. But symptoms of glare were common specially for those with high pre Ortho-k myopia and tended to effect night vision particularly during night driving [19,20]. Since, children don't require vision for night driving they responded particularly well. 90% of the children reported satisfactory good result under Ortho-k treatment in a study of 108 children during the year 2008 [23].

Aberrations:

As we know that Ortho-k improves more than, just the central refraction of an eye. This was supported by many studies which investigated the effect of treatment on higher order aberrations and contrast sensitivity. The generalized conclusions are as follows:-

1. Reduction in contrast sensitivity [22-27] including mesopic (low light) levels [19,28].
2. Coma and spherical aberrations increase to 3rd order and 4th order respectively [22,24,25].
3. Increase in corneal asymmetry [20,31].
4. Decentration of lenses increases unwanted aberrations, decreases contrast sensitivity [30,32] and is associated with monocular diplopia and glare [33].
5. Decentration tends to be temporal and is more common with greater initial astigmatism and smaller Ortho-k lenses [33].
6. Some of the higher order aberrations decreases during the day (mostly during first half of the day) [17].
7. After about 10 nights of wear, vision improves with an increase in zone 5 and reduction in defocus despite an increase in higher order aberrations [25].
8. After first 1-4 weeks of wear (depending on study's review period), the manifest refraction and uncorrected vision don't fluctuate significantly for at least 1 year [24,26].
9. Ortho-k is reversible. Refractive error, higher order aberrations, visual acuities and contrast sensitivity return near to base line 1-8 weeks after discontinuation [22,23].

Change In Accommodation And Convergence Function:

McLeod showed that Ortho-k did not result in any clinical or statistically significant difference in accommodation and convergence function [17]. This was disputed by Brand in 2008 who found that Ortho-k improved accommodation and convergence function in children [28]. Brand also hypothesized a reduction in the peripheral retina hyperopic defocus alters the ambient visual function resulting in normalization of convergence and accommodation.

Table 1 shows the result of McLeod and Brand influenced on their methods and designs used.

	McLeod	Brand
Patient entry criteria	Patients excluded if diagnosed with binocular vision dysfunction.	Patients not excluded if diagnosed with binocular dysfunction (amblyopia/ strabismus not accepted).
Patient age group	10-14 years old	1.0-36.8
Testing style	Mostly performed in phoropter	All performed in free space
Battery of tests	Near phoria Near vergence ranges Near point of accommodation Fused cross-cylinder Near relative accommodative range	Phoria distance and near Nearvergence ranges Near point of accommodation Accommodation facility MEM

Table 1: A comparison of studies done by McLeod and Brand

Some Other Clinical Signs Associated WithOrtho-k

Ortho-k is a safe procedure as long as patients are monitored regularly. The most common side effects that occur in patients with Ortho-k lenses are :-

- **Corneal Dimpling:**

After the first night of Ortho-k lens wear corneal dimpling may be noticed [19]. It had been suggested that the tear film between the cornea and Ortho-k lens is implicated in dimple formation.

- **Fibrillary Lines:**

In the anterior stroma fine, lightly curved fibrillary lines may be seen, but have no adverse effects on vision or ocular health [20]. There origins are unknown.

- **Corneal Sensitivity:**

Central and peripheral corneal sensitivity get reduced with extended Ortho-k lens wear [24].

- **Corneal Staining**

40% of the eyes undergoing Ortho-k treatment may show corneal epithelial staining, with no associated adverse events [23].

- **Lens Binding And Ocular Discharge:**

These are commonly reported problems during Ortho-k treatment which can be managed satisfactorily with ocular lubricants and lid hygiene [21].

- **Reduced Intra-Ocular Pressure Readings:**

Ortho-k results in an artificially low reading of intra-ocular pressure (IOP) measurements due to the thinned central cornea. Non contact tonometry is mostly influenced by the thickness of the cornea that is outside the expected norm [11].

According to a study of 90 eyes, the IOP readings were 13.5 $\pm$ 2.5 mmhg before Ortho-k treatment and 12.4 $\pm$ 2.7 mmhg after 52 weeks [22]. The author believes that the effect is minor especially for low corneal refractive changes, and it is unlikely that it would change the clinical management view for glaucoma. To obtain a more accurate IOP reading affected by Ortho-k, central corneal thickness may be measured by Pachymetry.

- **Microbial Keratitis:**

Microbial Keratitis is a potential vision threatening complication of Ortho-k. Vigilant cleaning of lenses and their accessories is crucial for reducing the risk factors of Microbial Keratitis. Common pathogens involved are Staphylococcus aureus, Pseudomonas aeruginosa and Acanthamoeba. Use Of Tap Water In Cleaning Of lenses is now inappropriate as a result of multiple cases of Acanthamoeba Keratitis.

Limitations Of Ortho-k Lenses:-

- **Residual Cylinder:**

Ortho-k lenses are designed for patients with low to moderate myopia (up to – 6.00D) with or without astigmatism (up to -1.75D). But beware of higher cylindrical corrections and possible residual cylinder correction- It may reduce the myopia but leave appreciable higher order aberration with uncorrected cylinders.

- **Astigmatism:**

It is addressed at low level of traditional Orthokeratology. Paragon signs is launching the dual axis system to address higher cylinder corrections. In the traditional design a lens fit on the flat meridian would decentered due to the differences between the flat and steep meridian. The dual axis have a spherical base curve with a unique peripheral system. This affords the two meridians varied depths within the return zone [19].

- **Full Distance Vs. Mono vision:**

In adult patients, a full distance correction or mono vision can be set as a goal. A full distance correction will required reading glasses however if the patient is fit with mono vision and does not like the effect the base curve can be adjusted to push fuller distance or an intermediate distance correction.

- **Ortho-k Is Reversible:**

The effects of Ortho-k are usually temporary and reversible. The fundamental considerations often appeals to many patients who are intimidated by the life long effect of LASIK or PRK. Adult patients are more comfortable knowing that Ortho-k lenses can be manipulated as needed to address presbyopia through out the child's life time.

Beyond Orthokeratology:

The concept of Orthoculogy (Ortho-C) has recently been proposed. It involves changes in lenses (and sclera in high myopia cases) instead of altering the cornea as with Orth-k. Flat rigid contact lenses are worn for up to 2 minutes. The draw from the contact lenses on the meniscus stimulates a neuromuscular response re-established distance focus by altering the curvature of the crystalline lens. After removal of the contact lens, the crystalline lens compensates by flattening out to rectify distance focusing.

II. Conclusion

Ortho-k an have both, a corrective and preventive/ control effect in childhood myopia. However there are substantial variations in changes in eye length among children. Wellcontrolled studies have demonstrated that myopia progression may be showed by 85 to 93.5% with Ortho-k. Other techniques has been developed to arrest myopic progression includes soft dual focused contact lenses and modified spectacle lenses which aims to reduce peripheral hyperopic defocus. To date, these have not proved to be as successful as Ortho-k further research may provide a better under standing of how Ortho-k reduces myopia progression and may lead to improve techniques, including the possibility of Orthoculogy.

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Consent for Publication :
Not applicable

Conflict Of Interest :
The author (editor) declares no conflict of interest, financial or otherwise.

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