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Hyperopic orthokeratology

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Hyperopic Orthokeratology

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Biographies

Seth Bruinsma was born in Manhattan, Kansas but was raised in Puyallup, Washington were he graduated from Puyallup High School in 1998. He earned his Bachelor's of Science degree in Zoology at the University of Washington in 2003. At present, Seth spends his time earning his Doctorate of Optometry at Pacific University College of Optometry.

Hiromasa Kanai was born in Tokyo, Japan and graduated from Senshu High School in 1990. He entered Senshu University and majored in Commerce from 1994-1998. Later Kikuchi College of Optometry 1998-2000. Hiromasa began studies at Pacific University majoring in English 2000-2001 and General Science in 2001-2003. He entered Pacific University College of Optometry in 2003 with to goal of obtaining a doctorate in 2007.

Jesse Petreman grew up in Kamloops, British Columbia, Canada and graduated from Brocklehurst Secondary High School in 1998. He earned a Bachelor's of Science degree in General Biology from Thompson Rivers University, Kamloops in 2003. He is currently working on his final year at Pacific University College of Optometry for his Doctorate of Optometry.

Introduction

Orthokeratology is the procedure of reducing or eliminating refractive ametropia by molding the cornea with a reverse geometry rigid gas-permeable contact lens. Today Orthokeratology is most commonly used to reversibly correct a patient's myopia and with-the-rule astigmatism. These lenses, normally worn while sleeping, can be utilized by a practitioner to increase or decrease the curvature of the cornea. Increasing the thickness and eccentricity of the cornea corrects for hyperopia, while decreasing the curvature of the cornea leads to treatment of myopia. Hyperopic Ortho-K is currently being researched but has not been FDA approved as of yet. In this paper we will address the current status of this modality along with the risks versus benefits for the use of Ortho-K to treat the hyperopic patient. There are many designs that are currently used to treat myopic patients, and although that technology is fairly new only slight changes need to be made to the lens design in order to treat hyperopia. There are a few different strategies that one can use to achieve an acceptable fit but as with any new technology there are limitations as to its use and who will find benefit with the modality.

Orthokeratology Lens Designs

The mechanism behind reducing the hyperopic condition has to do with specialized lens designs worn for continued wear that are properly fitted to a patient's eye. An Ortho-K lens is made up of several different zones, including one optical zone, a plateau zone, a fitting zone, an alignment zone and a peripheral zone [Figure 1].

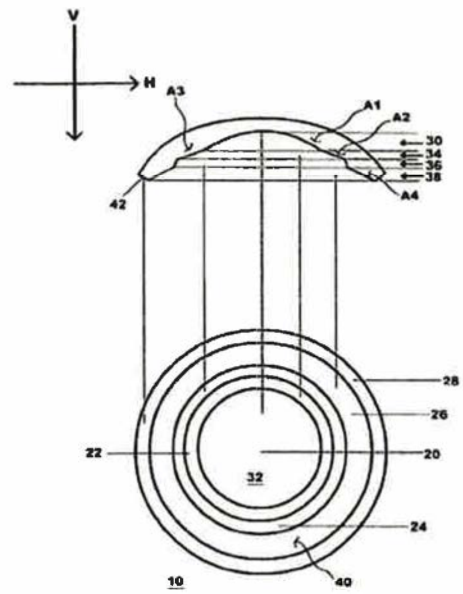
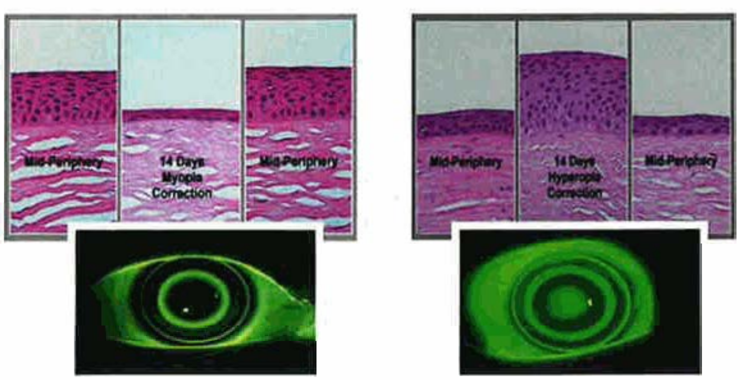


Figure 1. An orthokeratology contact lens for a patient's cornea comprised of an optical zone (20) having a curvature defined by a base curve (30); a plateau zone (22) coupled to said optical zone and extending radially therefrom, said plateau zone having a curvature defined by a plateau curve (34), said plateau curve being flatter than said base curve (30); a fitting zone (24) coupled to said plateau zone and extending radially therefrom, said fitting zone having a curvature defined by a fitting curve (36), said fitting curve being steeper than said plateau curve; an alignment zone (26) coupled to said fitting zone and extending radially therefrom, said alignment zone having a curvature defined by an alignment curve (38), said alignment curve being flatter than said fitting curve; a peripheral zone (28) coupled to said alignment zone and extending radially therefrom, said peripheral zone having a curvature defined by a peripheral curve (42), said peripheral zone forming an edge lift to act as tear reservoir.



The optical zones redistribute corneal tissue, or stroma, to increase or decrease the eccentricity of the cornea, depending on the patient's amount of refractive error. The now steepened central area is surrounded by a flat mid-peripheral ring as opposed to a thickening in this area which occurs during myopic Ortho-K. The plateau zone also aids this process through two specific mechanisms: a positive molding effect which pushes the corneal tissue inward, causing a congregation of epithelial and stromal cells and a negative molding effect to flatten the mid-peripheral cornea. The remaining zones allow for tear distribution and lens centering.

Corneas have been successfully steepened in cats by investigators Jennifer Choo, Pat Caroline, Dustin Harlin, and Bill Myers, PhD [Figure 2]. The results showed a reduction of cells in the mid-periphery and an increase centrally, which suggests a redistribution of epithelial cells as the main orthokeratology effect. Exactly how the results in cats translate to human subjects is unknown.

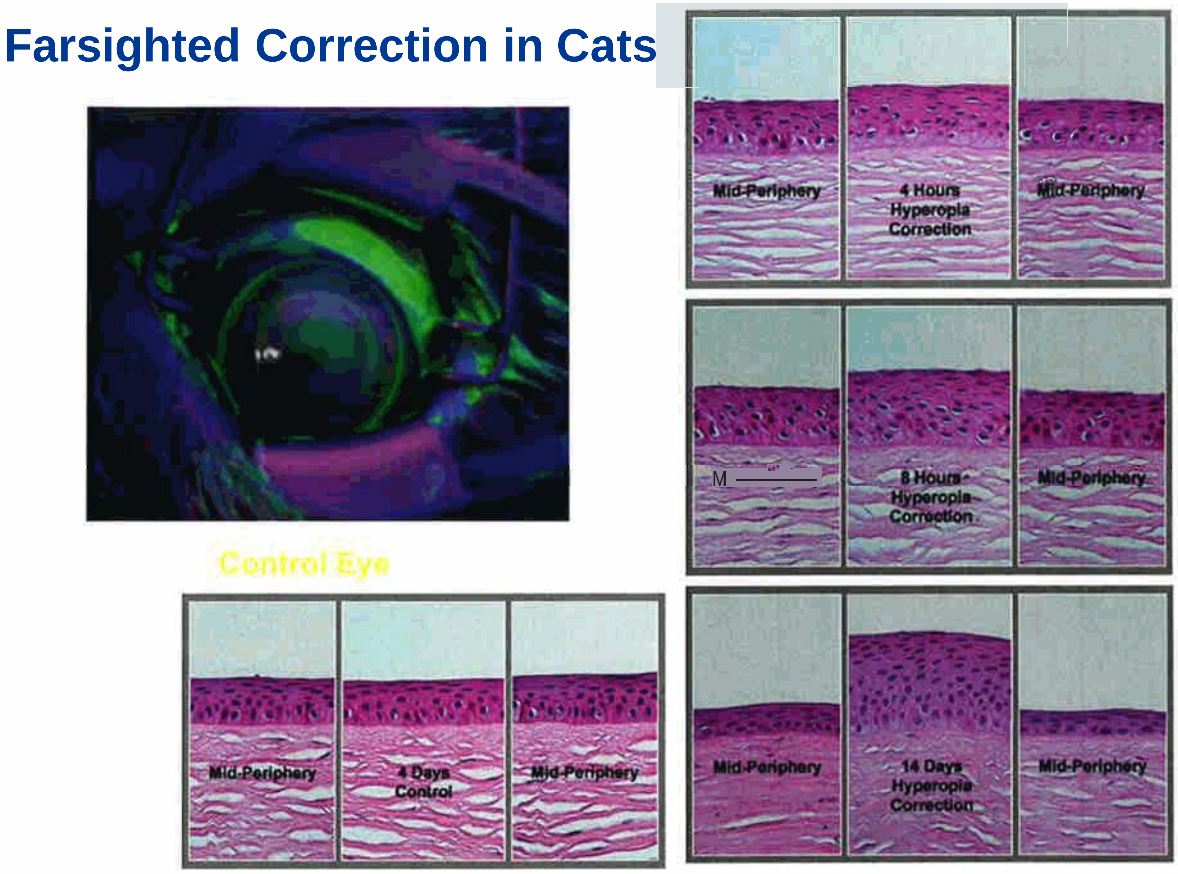


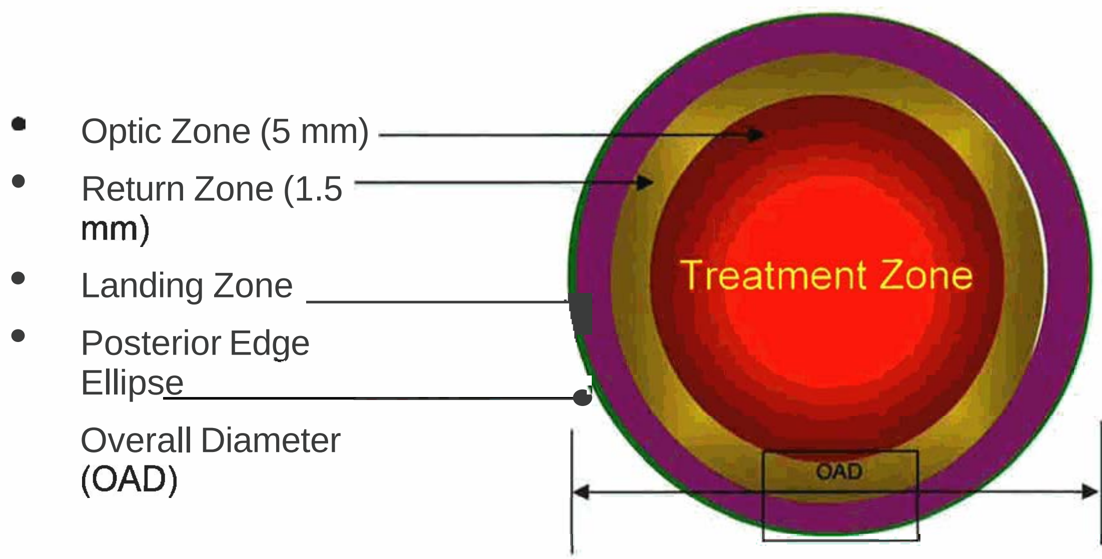
Figure 2: Morphologic changes in cat epithelium following continuous overnight lens wear with Paragon CRT fitted for corneal steepening.

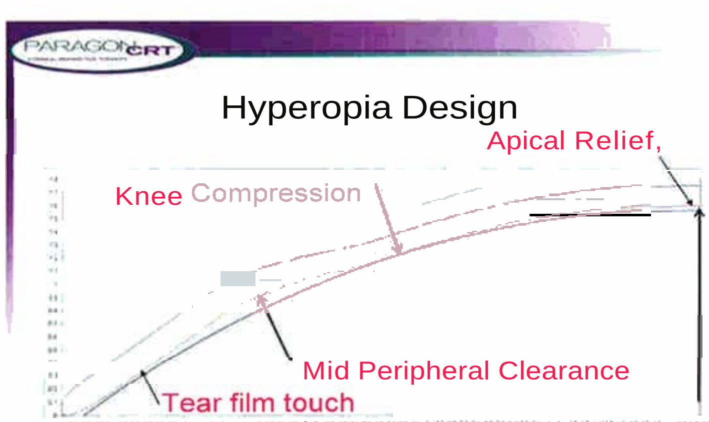
Hyperopic CRT Lens Design vs. Myopic Lens Design

Reverse geometry Ortho-K lenses are manufactured by several companies using one of the two FDA approved technologies for treating myopia and additional research has found that by adjusting the fit of these myopic lenses they can be used to treat hyperopia. Each technology utilizes specialized gas permeable lenses to reshape the cornea with lens materials that offer high oxygen permeability. This is important for maintaining sufficient oxygen flow to the cornea while the patient sleeps. Paragon Vision Science makes a lens under the trademark "CRT" (Corneal Refractive Therapy). Bausch & Lomb's "Vision Shaping Treatment" is a choice of four approved designs that only certified practitioners can fit to a patient's corneas. The four designs in the VST group include "BE Retainer" delivered by BE Enterprises Inc., "Contex OK-E System" backed by Contex Inc., "DreamLens" supported by Dreamlens Inc, "Emerald" backed by Euclid Systems Corp, and "Fargo" backed by C&E GP Specialists. There are only a handful of other Ortho-K lens brands that are FDA approved for overnight wear. Currently there are no studies underway for any other lens designs.

Paragon CRT lens design allows for corneal steepening through Precise Control of Treatment through Proximity Control Technology™. The Hyperopia CRT design breaks down into three functional zones: the optic zone, the landing zone, and the reverse zone. The shape of the central optic zone provides the desired curvature change and resulting change in refractive power. A typical optic zone may range from 5.00 to 7.00mm in diameter. The landing zone, or peripheral curve/alignment curve, as it is often called, is responsible for lens centration, which is crucial in Ortho-K. It should be fettle in alignment with the slope of the peripheral cornea. The peripheral curve can be spherical, aspherical, or simply tangent to the peripheral cornea. Alternating the peripheral curve or landing zone angle alters the sagittal height of the lens and varies the amount of refractive correction. The goal with Ortho-K is to ensure a thin layer of tear is between the lens and the apex of the cornea. Since the exact sagittal depth is often unknown practitioners must manipulate the height of the lens based on flourescein pattern evaluation and post-treatment topography measurements. The reverse zone is what connects the fixed optic zone with the alignment curve, bringing the lens back down and into contact with the cornea.

Paragon CRT-H





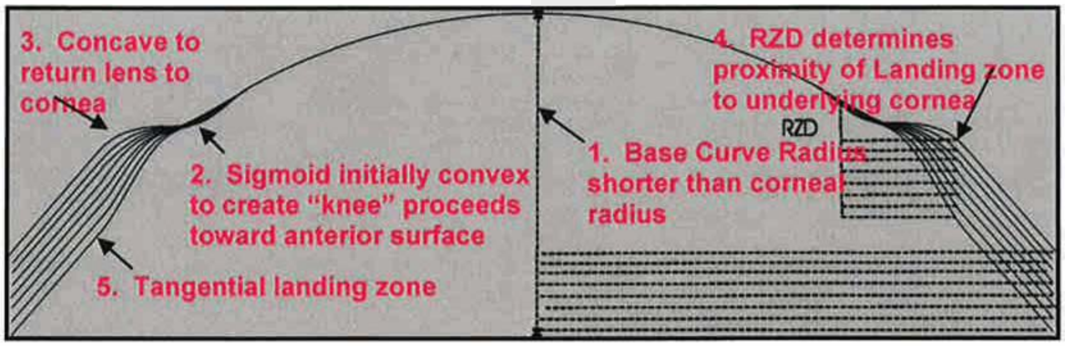
The convex "knee" creates adequate thinning, apical relief allows for central thickening, and the width (radius) of the knee is critical to treatment. The negative pressure between the landing zone and peripheral cornea creates the necessary compression force.

Legerton-Meyers, the designers behind the US patent application "Example

6”, knew that for the precise application of the treatment zone they needed to understand the sagittal depth of the cornea being treated. Then they would create variable mechanisms for applying that treatment with the appropriate sagittal lens configuration. The control of precise treatment is provided primarily by the variable Return Zone Depth.

Legerton-Meyers
US Patent Application "Example 6"

Sigmoid Connecting Geometry



Precise Control of Treatment
through Proximity Control Technology™

Hyperopic CRT Fitting Strategy

To correct hyperopia with the CRT lens the practitioner fits the lens to the individual cornea by the same principle of sagittal depth calculation as in myopic Ortho-K. The lens designs for hyperopic and myopic correction with CRT are identical, and whether the central cornea eccentricity is increased or decreased is based on how the CRT lens is fit. The first step is to calculate the appropriate base curve radius (BCR). The desired base curve radius is determined by taking the patient's flat K reading and adding 0.50D to provide for increased steepness. The dioptric value of the desired correction is then added to the modified Flat K. For example, if a patient has a flat K of 42.00 and 0.50D is added, the resulting value is 42.50. Next, if 2.00D is the desired correction it is then added to 42.50D value. The base curve radius is then equal to 44.50D/7.60mm.

The next step in the process is to determine the Return Zone Depth (RZD) and Landing Zone Angle (LZA). These values are determined by utilizing the current fitting CRT slide rule developed for myopic correction. The original Flat K (42.00D) and refractive change desired (2.00D) are inputted in the slide rule. The suggested RZD is read off the slide rule and this value is lessened by 50 microns. For example if the slide rule calculates the RZD to be 525 microns this value needed to be reduced by 50 microns with the final value for RZD being 475 microns. The necessary LZA is determined by reading the calculated value right off the slide rule. In the above case the appropriate LZA would be 32.

The goal of hyperopic Ortho-K with CRT is to use diagnostic lenses with BCR steeper than flat K. To help troubleshoot fitting the following may be considered. All lenses will touch the cornea at the knee if the RZD is shallow enough. Consequently if the RZD is too deep the knee will lift off.

Furthermore, the sodium fluorescein pattern will appear green from center to landing zone. If the RZD is too shallow the landing zone will lift off. In this case the knee will touch circumferentially but the lens will de-center and tip and tilt just like in myopia treatment. The landing zone angle is evaluated in the same manner as in myopia treatment. The ideal is lens centration within 0.5 mm of the pupil center. A minimum of 4 mm treatment zone and edge lift between 0.2 mm and 0.6 mm should be utilized.

Patient Selection and Safety

Proper patient selection is a critical part of the orthokeratology process. Finding the right patient to fit ensures less chance of adverse effects. Factors to consider when selecting a patient for orthokeratology include: amount of refractive error, pupil size, physiological and pathological status of the eye, and whether the patient is a current contact lens wearer.

At the present time the amount of correction for hyperopia and astigmatism using this method is around +3.00D with less than 1.25D of cylinder. Higher amounts may be able to be corrected but suggests too high of an eccentricity and limited optical zone diameter in the lens to reveal any worthwhile statistics above 3D at this time. The correction of astigmatism is usually limited to about 50% of central, with the rule corneal astigmatism can be corrected with standard lenses.

Pupil size in Ortho-K fitting has significant importance because with this procedure, as well as with LASIK, higher order aberrations are increased dramatically. A pupil size of around 6mm in dim lighting should be easily treated with a 4-5 mm optic zone diameter. Lens centration as well will interact with the size of the pupil and must be large enough to accommodate the pupil and be centered on it.

Deep-set eyes and loose eyelids, as well as lower than normal upper eyelids and narrow apertures, are all mentioned as potential anatomical limitations of Ortho-K. These are problematic because they interfere with factors that are essential for centering the lens and achieving a good contact lens fit. The age of the wearer is also a contraindication due to larger pupil sizes in children and older wearers, which have reduced responses to corneal molding (Jayakumar & Swarbrick 2005). Ortho-K has occasionally been associated with corneal ulcer development resulting in corneal scarring and vision loss. Such a complication is thought to be more frequent in children, although this may be attributed to the fact that the majority of Ortho-K wearers are children. Wearing Ortho-K lenses in a closed-eye environment creates a more hypoxic situation compared to that of the opened eye. Corneal hypoxia, with prolonged overnight contact lens wear, allows bacteria to bind more easily to the corneal epithelium, providing a risk factor for infection. Furthermore, complications may also arise due to the patient's inability to maintain appropriate hygiene.

Other contraindications are corneal dystrophies, degenerations, and anterior-segment disease. Keratoconus and pellucid marginal degeneration are also considered absolute contraindications and need to be carefully ruled out before starting any Ortho-K treatment.

The Future

The orthokeratology effect happens rapidly and corneal curvature changes appear after just 10 minutes of lens wear. In both myopic and hyperopic fits there has been little regression during the day after a night of wearing this lens. However, the effects are completely reversible in just one month of cessation of wear. Hyperopic Ortho-K shows promise for the correction of not only those patients with a far-sighted eye but also for emerging presbyopes. Given the number of current presbyopes this method of treatment could prove very valuable in an orthokeratologist's kit. While there are many clinical trials still to be performed and written up, we look forward to continuing this research in an area that shows great promise.

Conclusion

The specific mechanism for how orthokeratology works remains a mystery, yet many attribute the affects it has to changes in corneal curvature, which involves both epithelial and stromal manipulation in the mid-periphery. The correction of hyperopia has gained less attention within the realm of orthokeratology. We now know that correction of hyperopia is feasible but seems to be limited by optical zone diameter and a patient's motivation to continue with modality long enough to allow adequate steepening. The corneal steepening response is much slower than the flattening response in myopia. Future lens designs incorporating back-surface geometrics for hyperopia or lenses to create aspheric corneas for presbyopia will be important modalities for future research treatments with orthokeratology.

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