

Pacific University

CommonKnowledge

---

College of Optometry

Theses, Dissertations and Capstone Projects

---

5-2003

## Average eccentricity values of the human cornea at 7, 8, and 9 mm chords

John Reeves  
*Pacific University*

### Recommended Citation

Reeves, John, "Average eccentricity values of the human cornea at 7, 8, and 9 mm chords" (2003). *College of Optometry*. 1453.

<https://commons.pacificu.edu/opt/1453>

This Thesis is brought to you for free and open access by the Theses, Dissertations and Capstone Projects at CommonKnowledge. It has been accepted for inclusion in College of Optometry by an authorized administrator of CommonKnowledge. For more information, please contact [CommonKnowledge@pacificu.edu](mailto:CommonKnowledge@pacificu.edu).

---

## Average eccentricity values of the human cornea at 7, 8, and 9 mm chords

### Abstract

Eccentricity is a value that describes how much the peripheral curve radius flattens with respect to the apical curve radius. Much of the fitting of RGPs takes place in the periphery; this is why it is important to take into account eccentricity when fitting lenses. 100 subjects had eccentricities measured of their right eye at 7, 8, and 9 mm chords and the data analyzed. The average eccentricities are 0.572, 0.603, and 0.635 for the 7, 8, and 9 mm chords respectively. The average values show greater eccentricities as you move into the periphery of the cornea, demonstration that eccentricity can change a great deal with small changes in chord length. We have shown that there is a large, well distributed range of values at each chord. Very few of those sampled would have eccentricities that would not change the peripheral curve radius by  $\pm 1/8$ th D from the expected peripheral curve radius at a given chord. Furthermore, small changes in eccentricity can change the peripheral curve radius a great deal. Because of this large distribution of values, and because a small change in eccentricity can have great impacts on peripheral steepness, it is important to take into account eccentricity, and the position where the lens fits on the cornea when fitting RGP lenses.

### Degree Type

Thesis

### Degree Name

Master of Science in Vision Science

### Committee Chair

Patrick Caroline

### Subject Categories

Optometry

## Copyright and terms of use

If you have downloaded this document directly from the web or from CommonKnowledge, see the "Rights" section on the previous page for the terms of use.

**If you have received this document through an interlibrary loan/document delivery service, the following terms of use apply:**

Copyright in this work is held by the author(s). You may download or print any portion of this document for personal use only, or for any use that is allowed by fair use (Title 17, §107 U.S.C.). Except for personal or fair use, you or your borrowing library may not reproduce, remix, republish, post, transmit, or distribute this document, or any portion thereof, without the permission of the copyright owner. [Note: If this document is licensed under a Creative Commons license (see "Rights" on the previous page) which allows broader usage rights, your use is governed by the terms of that license.]

Inquiries regarding further use of these materials should be addressed to: CommonKnowledge Rights, Pacific University Library, 2043 College Way, Forest Grove, OR 97116, (503) 352-7209. Email inquiries may be directed to: [copyright@pacificu.edu](mailto:copyright@pacificu.edu)

AVERAGE ECCENTRICITY VALUES  
OF THE HUMAN CORNEA  
AT 7, 8, AND 9 MM CHORDS

BY

JOHN REEVES

A thesis submitted to the faculty of the  
College of Optometry  
Pacific University  
Forest Grove, Oregon  
for the degree of  
Doctor of Optometry  
May 2003

Advisor:

Patrick Caroline, COT, FAAO

John Reeves

*John Reeves*

Patrick Caroline, COT, FAAO

*Patrick Caroline*

**Biography:**

John Reeves attended Carroll College in Helena, MT where he earned a bachelor of arts degree in Biology. He currently attends Pacific University College of Optometry and will graduate in May 2003. He plans to practice optometry in the northwestern United States.

**Acknowledgments:**

I would like to thank Patrick Caroline, James Reeves, and John Rinehart for their insight, guidance, and patients during this project.

**Abstract:**

Eccentricity is a value that describes how much the peripheral curve radius flattens with respect to the apical curve radius. Much of the fitting of RGPs takes place in the periphery; this is why it is important to take into account eccentricity when fitting lenses. 100 subjects had eccentricities measured of their right eye at 7, 8, and 9 mm chords and the data analyzed. The average eccentricities are 0.572, 0.603, and 0.635 for the 7, 8, and 9 mm chords respectively. The average values show greater eccentricities as you move into the periphery of the cornea, demonstration that eccentricity can change a great deal with small changes in chord length. We have shown that there is a large, well distributed range of values at each chord. Very few of those sampled would have eccentricities that would not change the peripheral curve radius by  $\pm 1/8^{\text{th}}$  D from the expected peripheral curve radius at a given chord. Furthermore, small changes in eccentricity can change the peripheral curve radius a great deal. Because of this large distribution of values, and because a small change in eccentricity can have great impacts on peripheral steepness, it is important to take into account eccentricity, and the position where the lens fits on the cornea when fitting RGP lenses.

## **Introduction:**

With the innovation of the corneal topographer, practitioners could more easily gather information about the cornea, especially the periphery. This information could be used to aid in fitting of soft contact lenses, rigid gas permeable contact lenses, and more recently, reverse geometry lenses. Conventional keratometers only analyze the central 3 mm when in the straight ahead position. Peripheral corneal information is obtainable with keratometers by having the patient look up, down, left, or right. However, peripheral information is difficult, and often inaccurate, to measure if you are not analyzing the 180<sup>th</sup> or 90<sup>th</sup> meridian. In addition, this method is time consuming when you consider that a topographer gathers information about the entire cornea in one exam.

Corneal eccentricity is a value describing how much the peripheral cornea radius has flattened with respect to the apical radius. The formula for corneal eccentricity is:

$$e = \sqrt{[(P^2 - A^2) / (d/2)^2]}$$

Where e is the eccentricity; P is the peripheral curve radius in mm, A is the apical curve radius in mm, and d is the chord length in mm. A chord is a length that runs from one side of the cornea to another, running perpendicular and through the visual axis. A chord is roughly equal to twice the radius from the apex of the cornea to the point of interest on the cornea. For example, a point that is 3 mm from the apex of the cornea would be at a 6 mm chord. When fitting a reverse geometry lens on an eye with a large eccentricity, you will have to flatten the fitting curve from the apical radius to get a proper fit. In contrast, you may use the apical radius as your fitting curve radius on an eye with a low eccentricity.

Information about the peripheral cornea, especially eccentricity, is particularly useful in fitting RGPs due to the fact that fitting of the lenses largely takes place in the



mid-peripheral cornea, and RGPs often require a more exact fit than soft contacts lenses. Furthermore, reverse geometry lenses require a more exact fit than normal RGPs due to the need for the lenses to center well. Without well centered reverse geometry lenses, the treatment zone will not be on the visual axis, giving less than desirable visual acuity.

From the equation for eccentricity above, and using an apical radius of 7.80 mm (43.25 D) and an eccentricity of 0.50, at a 9.0 mm chord, the peripheral radius is 8.19 mm (41.25D). This means you would have to take into account a 2.00 D flattening in the periphery when designing your lens. Using the same eccentricity and apical radius at an 8 mm chord, you would have to take into account approximately 1.37 diopters of difference in the peripheral curve. If we could use eccentricity information about the peripheral corneal steepness and the effects it has at various lengths from the apex, it would be theoretically easier to design RGP lenses.

Using a 10 mm reverse geometry lens as a model, the optical zone diameter is approximately 6.0 mm, the reverse curve is 0.6 mm wide, the fitting curve is 1.0 mm wide, and the peripheral curve is 0.4 mm wide. This means that the fitting touch of the lens can occur any where from a chord of 7.2 to 9.2 mm along the fitting curve. Ideally, you need to take into account the eccentricity and the position where the lens is touching the eye to properly generate the fitting curve on your RGP and reverse geometry lenses.

Dr. Joe, in his article in the Journal of the American Optometric Association, showed a correlation between the eccentricity of an eye and the relative change in the post-Ortho-K keratomeries.<sup>1</sup> This could be another use for e values besides fitting and designing lenses. Previously, factors such as initial topographies, amount of astigmatism, and desired flattening were used as indicators of ortho-K success. If we had more

information about eccentricity, we could use it as an additional way to predict successful ortho-K.

Knowing how eccentricity can affect lens design, we wanted to determine what the average eccentricity and distribution are of the human cornea. Also, we wanted to know what the eccentricity is at various chords of the cornea since all RGP do not fit at the same place. It would be beneficial to know how the eccentricity values are distributed in the general population. If the range is tightly distributed, then it may be possible to assume a standard eccentricity value that will work for most patients.

### **Methods:**

Corneal topographies were taken of the right eye of 100 optometry students using the Medmont topographer. All subjects were in good ocular health and did not have any corneal dystrophies, degenerations, or previous refractive surgeries. The Medmont topographer was used due to its high reliability and repeatability and also because it takes multiple readings during each exam to give an average value.<sup>2</sup> The Medmont also automatically finds the flat median of the eye and allows you to find the eccentricity value along any meridian and at any distance from the apex. It calculates the eccentricity by averaging the nasal and temporal values along the specified meridian at a particular distance on either side of the apex.<sup>2</sup> All values were taken along the flat meridian because reverse geometry lenses are fit on this meridian. Eccentricity values were taken at the 7, 8, and 9 mm chords.

### **Data and Results:**

Average eccentricity values were calculated at the various chords. The values were 0.572 at 7 mm, 0.603 at 8 mm, and 0.635 at 9 mm. These values are summarized in table 1.

**Table 1: Average eccentricity values at the various chords**

	7 mm chord	8 mm chord	9 mm chord
Average	0.572	0.603	0.635
Standard deviation	±0.125	±0.138	±0.141

The average value of the eccentricity increases as you go more into the periphery. This can be anticipated because the cornea becomes more aspheric as you move away from the apex. Also, the distribution shows a slide toward higher eccentricity as you move to the periphery as shown in Figures 1, 2, 3, and 4. For simplicity, the distribution was divided into the categories: low ( $e = 0.10$  to  $0.39$ ), medium ( $e = 0.40$  to  $0.69$ ), and high ( $e = 0.70$  to  $0.99$ ). At a 7 mm chord, 8% of the subjects had eccentricities in the low range, whereas 6% were found in this category at the 8 and 9 mm chord. The medium values show a decreasing occurrence trend as you move into the periphery: 79% for the 7 mm chord, 72% for the 8 mm chord, and 60% for the 8 mm chord. Contrary to this, the high values show increasing occurrence as you move into the periphery: 13%, 22%, and 34% for the 7, 8, and 9 mm chords respectively.

Analyzing the peripheral corneal at a 7 mm chord, using the formula for eccentricity, an apical radius of 7.80 mm, and the average  $e$  value of 0.572 from above, gives us a peripheral radius of 8.05 mm (41.88), a difference of 1.38 D from the apical radius. The question now is how much does the  $e$  value need to vary to change the peripheral cornea by  $\pm 1/8^{\text{th}}$  D?  $1/8^{\text{th}}$  diopter was chosen because RGPs are rarely made with specifications more exact than to the  $1/8^{\text{th}}$  diopter. With an apical radius of 7.80 mm, the  $e$  value can range from 0.557 to 0.602 and have the peripheral curve be within  $\pm 1/8$  D of the expected peripheral curve radius of 8.05 mm, based on the average  $e$  value at this chord. (Table 2) Only twenty of the 100 would have eccentricities that would give peripheral curve radius within  $\pm 1/8^{\text{th}}$  D of the expected average peripheral curve radius.

(Table 3) To state this another way, with an apical radius of 7.80 mm at a 7 mm chord, it takes a change in eccentricity of 0.015 less or 0.030 more to change the peripheral curve by 1/8<sup>th</sup> D.

**Table 2: Average e values, expected peripheral curve radius, and eccentricity needed to change the expected peripheral curve radius by 1/8<sup>th</sup> D using an apical radius of 7.80 mm**

	Average e value	Expected peripheral curve radius using average e value	Eccentricity needed to change the peripheral curve radius by $\pm 1/8^{\text{th}}$ diopter	
			low value	high value
7 mm chord	0.572	8.05 mm	0.557	0.602
8 mm chord	0.603	8.16 mm	0.572	0.616
9 mm chord	0.635	8.31 mm	0.617	0.650

At the 8 mm chord, using a 7.80 mm apical radius and average e value of 0.603, the peripheral curve radius is expected to be 8.16 mm (41.36 D), a variation of 1.88 D from the apical radius. At this chord, the e value can range from 0.573 to 0.616 and have the peripheral curve be within  $\pm 1/8^{\text{th}}$  D of the expected peripheral curve radius of 8.16 mm. (Table 2) Seventeen of those sampled were within  $\pm 1/8^{\text{th}}$  D of the expected average peripheral curve radius. (Table 3)

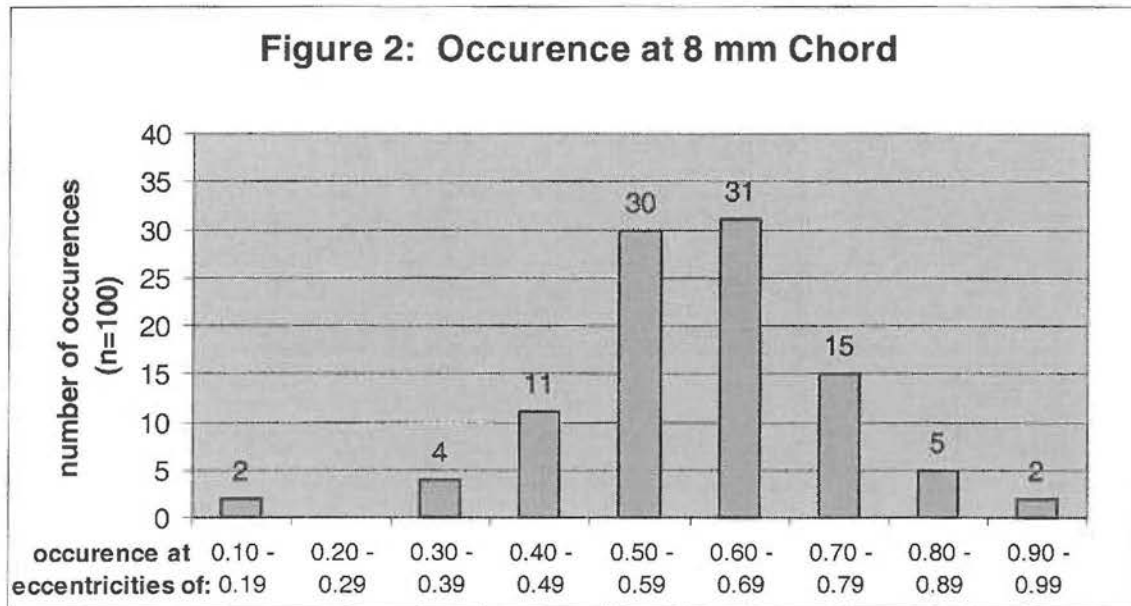
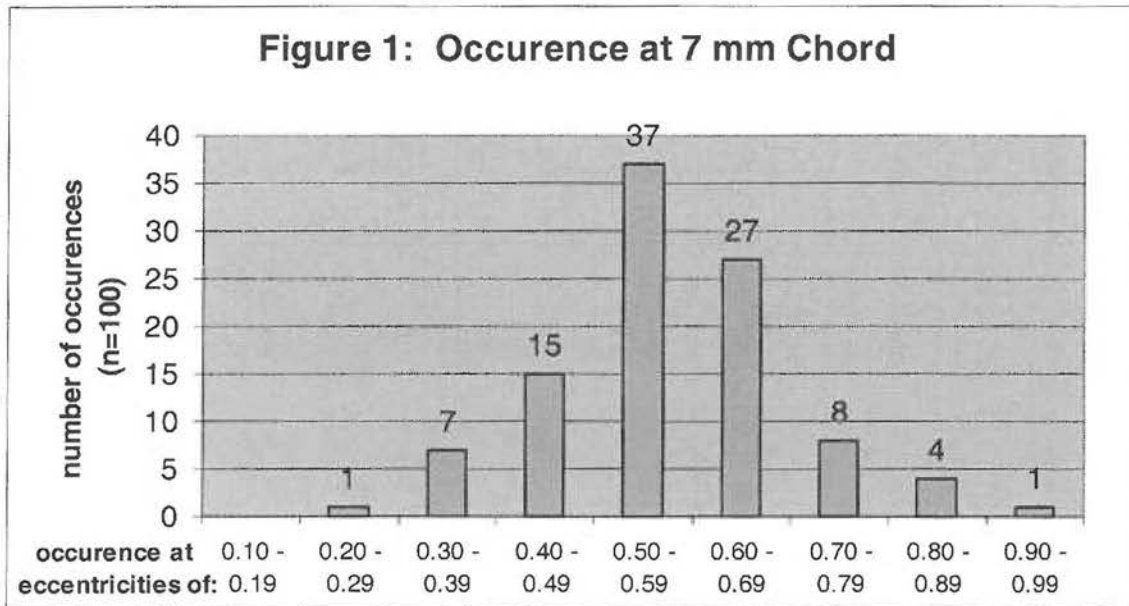
**Table 3: Percent of subjects sampled having eccentricities that are within  $\pm 1/8^{\text{th}}$  diopter of the expected average peripheral curve radius using an apical radius of 7.80 mm**

	% of subjects sampled
7 mm chord	20%
8 mm chord	17%
9 mm chord	5%

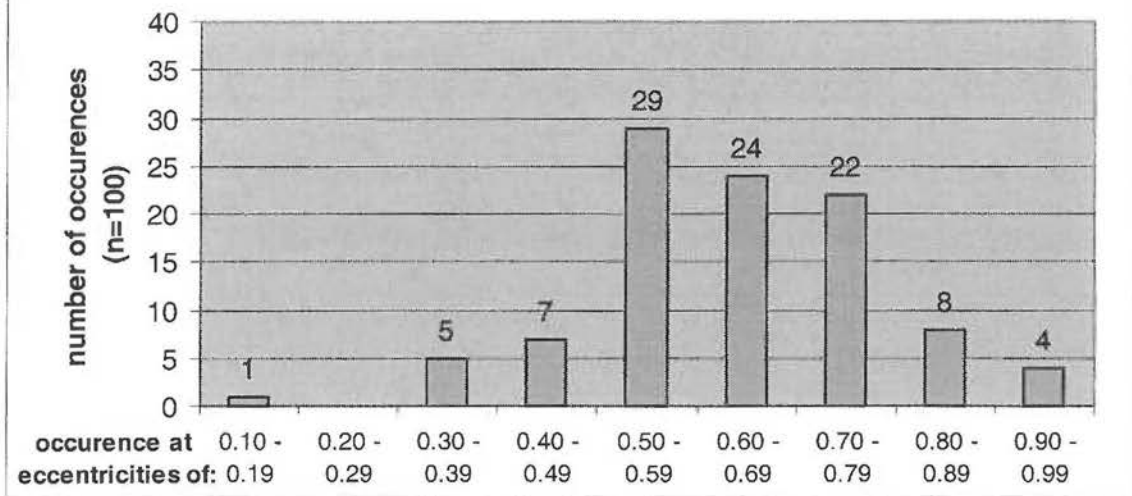
Looking at the 9 mm chord and the same criteria as with the 7 and 8 mm chords, the expected peripheral radius is 8.31 mm (40.63 D), a difference of 2.62 D from the apical radius. E values between 0.617 and 0.650 would give expected peripheral curve radius values that are within  $\pm 1/8^{\text{th}}$  diopter of the expected average peripheral curve

radius. (Table 2) At this chord, only 5 of those sampled would fit this criterion. (Table 3)

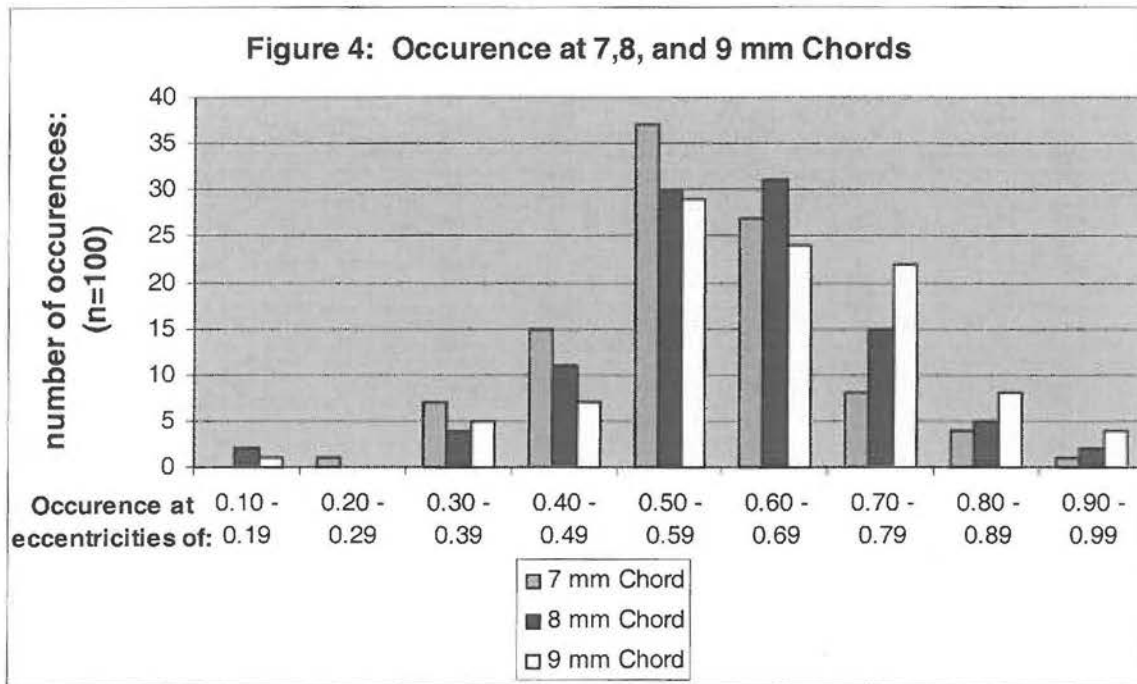
All of these values would be different using an apical radius other than 7.80 mm.



**Figure 3: Occurrence at 9 mm Chord**



**Figure 4: Occurrence at 7,8, and 9 mm Chords**



**Conclusion:**

We have shown that there is a general trend of higher eccentricity as you move more into the periphery of the eye. The farther you move peripherally on an individual eye, the greater the eccentricity, and also the population average for eccentricity increases

as you move more peripherally. There is a fairly large distribution of values at each position measured. Even though an average value was calculated at each position, the average value does not represent a large percentage of the population. At the 9 mm chord, only 5% had e values that would give peripheral curves within  $\pm 1/8 D$  of the expected peripheral curve radius, only 17% meet this criterion at the 8 mm chord, and 20% at the 7 mm chord. One average value cannot be assumed to be true in the vast majority of the population thus emphasizing the need to take eccentricity into account when fitting any type of RGP lens.

All formulas above were calculated using an apical radius of 7.80 mm (43.25), assuming that all eyes have the same apical radius. Since we know that this is not true, it would be beneficial to see in future studies how eccentricity and the apical radius correspond to each other. It would also be interesting to determine to what extent the eccentricities show a different average and distribution when the apical radius is taken into account. In addition, the numbers would be different if a keratometer was used to measure corneal steepness instead of a topographer. A keratometer actually measures steepness at a 3 mm chord, and does not measure the apical radius. Without a true value for apical radius, one cannot technically calculate eccentricity and will only get a gross estimate.

If you use a computer program and topographer to design your lenses, even if it is one that takes into account corneal eccentricity, you don't know where the lens is touching the cornea without putting a lens on the eye. The eccentricity that is given by the topographer may not be at the correct chord. We have seen how eccentricity can vary

greatly on the same eye as you move into the periphery, even by moving 0.5 mm on the cornea.

It would be beneficial if there was an average eccentricity of the human cornea as a starting point whether or not you use eccentricity to design your lenses. This would save the practitioner and the patient time and heartache. However, we have shown this not to be the case. Eccentricities vary widely from person to person and we have shown that a small change in eccentricity can produce a large change in the peripheral curve radius. It is important to take into account as many factors as possible when fitting any type of RGP. This includes not only the value of the eccentricity but also the position on the cornea where you measure the eccentricity.



## References:

1. Joe J, Marsden H, Edrington T. The Relationship Between Corneal Eccentricity and Improvement in Visual Acuity with Orthokeratology. *Journal of the American Optometric Association* Vol. 67, No. 2, Feb. 1996: 87-97
2. Cho P, Lam A, Mountford J, NG L. The Performance of Four Different Corneal Topographers on Normal Human Corneas and Its Impact on Orthokeratology Lens Fitting. *Optometry and Vision Science* Vol. 79, No. 3 March 2002: 175-183
3. Tang W, Collins MJ, Davis B. The Accuracy and Precision Performance of Four Videokeratoscopes in Measuring Test Surfaces. *Optometry and Vision Science*, Vol 77 No. 9, Sept. 2002: 483-491
4. Mountford J, Caroline P, Noack D. Corneal Topography and Orthokeratology: Pre-fitting Evaluation. *Contact Lens Spectrum* April 2002: 38-44
5. Mountford J, Noack D. Corneal Topography and Orthokeratology: Post-fit Assessment. *Contact Lens Spectrum* June 2002: 25-31