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Irisometer

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Abstract
The corneal diameter has a formidable influence on the sagittal height of the anterior eye. Typically, practitioners use the sole measurement of keratome try readings in an attempt to accurately predict the proper inner sagittal depth of a contact lens. However, the sagittal depth of the anterior eye is influenced by other anatomical factors such as corneal asphericity, curvature of the paralimbal sclera and the corneal diameter. The Irisometer, an instrument used to measure the horizontal visible iris diameter, was developed with the intentions of incorporating the simplicity of the hand-held ruler along with the accuracy of the slit lamp based reticule. The Irisometer was tested on 35 subjects, which revealed favorable test results showing the Irisometer to be both accurate and simple to use. The measurement of the horizontal visible iris diameter has an important contribution to successful contact lens fitting. It is therefore concluded that the contact lens practitioner would benefit from having the Irisometer in his armamentarium in order to obtain quick and accurate measurements of the corneal diameter.

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IRISOMETER

By

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A thesis submitted to the faculty of the

College of Optometry
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Advisor: Patrick J Caroline, COT, FAAO
SIGNATURES

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BIOGRAPHY

Rania Monticello graduated in 1995 from the University of Washington with a degree in Psychology. She received her Doctorate of Optometry from Pacific University in 2001. Ranai enjoyed working with Amigos while in optometry school and headed a trip to Egypt in the fall of 2000. Her present plans are to practice in the state of Washington with an emphasis in pediatrics.

Dallin Rice Received his Bachelor of Visual Science from Pacific University in 1999. He later received his Doctorate of Optometry in 2001. Dallin is a member of the BSK Honor Fraternity. He anticipates working in a private practice in the State of Utah with an emphasis in Sports vision and Contact lenses.
ABSTRACT
The corneal diameter has a formidable influence on the sagittal height of the anterior eye. Typically, practitioners use the sole measurement of keratometry readings in an attempt to accurately predict the proper inner sagittal depth of a contact lens. However, the sagittal depth of the anterior eye is influenced by other anatomical factors such as corneal asphericity, curvature of the paralimbal sclera and the corneal diameter. The Irisometer, an instrument used to measure the horizontal visible iris diameter, was developed with the intentions of incorporating the simplicity of the hand-held ruler along with the accuracy of the slit lamp based reticle. The Irisometer was tested on 35 subjects, which revealed favorable test results showing the Irisometer to be both accurate and simple to use. The measurement of the horizontal visible iris diameter has an important contribution to successful contact lens fitting. It is therefore concluded that the contact lens practitioner would benefit from having the Irisometer in his armamentarium in order to obtain quick and accurate measurements of the corneal diameter.
INTRODUCTION

Successful fitting of soft contact lenses can be facilitated with the knowledge and understanding of the anatomical components that contribute to the overall sagittal height of the anterior eye. These are:

1. Corneal Diameter
2. Radius of Curvature of the Central Cornea
3. Mid-peripheral and Peripheral Corneal Topography (Shape Factor)
4. Scleral Radius of Curvature
5. Scleral Shape Factor.

Corneal Diameter
"Corneal diameter is determined by measuring the horizontal length of the visible iris diameter. Although the cornea itself extends somewhat beyond the bounds of the iris, the discrepancy is small and, for practical purposes, can be ignored." The typical iris diameters range from 10 to 12.5 mm.

Radius of Curvature of the Central Cornea
The central radius of curvature can be measured by:

1. Keratometry
2. Photo-keratoscopy
3. Videokeratography (Simulated keratometry values).

The values are commonly expressed as dioptic radii of curvatures along the two principle meridians of the cornea.

Example: Horizontal meridian: 42.00 @ 180
         Vertical meridian: 44.00 @ 90

For purposes of sagittal height calculations, the apex of the cornea should be the point reference, since it represents the highest elevation. "This measurement is restricted to a small area and is not representative of the entire corneal contour." Therefore, the practitioner must use caution when only considering keratometry readings for the determination of the entire corneal topography. For practical purposes, the "overall" radius of the central cornea can be accomplished by calculating the mean radius of the two principle meridians.

Example: From the above example:
         \[ \frac{(42.00 + 44.00)}{2} = 43.00 \] (Mean Radius)
Mid-Peripheral and Peripheral Corneal Topography (Shape Factor)
The shape (angle) of the peripheral cornea can have a major influence on the sagittal height of the cornea. This measurement remains the most difficult to accurately assess. Modern corneal mapping techniques provide some insight as to the shape of the paralimbal cornea.
Scleral Radius and Shape Factor

Studies by Young, et al., have shown that the contributions of the scleral radius and scleral shape factor to the overall sagittal height of the eye are negligible.

Young, et al., presented the following data which illustrates the influences that these anatomical structures have on the sagittal height of the eye.

![Chart](image)

Figure 3. Effect of ocular parameters on sagittal height measurements (mm)

From these results it is clear the impact the corneal diameter has on the ocular sagittal height. There is a tendency for corneas with larger diameters to be flatter and vice versa. “In most cases, for a successfully fitting lens, the inner sagittal depth of the contact lens is greater than that of the corresponding anterior eye. A tightly fitting lens for instance, can be considered as having too great a sagittal depth for the eye that it is intended to fit.”

When we look at the guidelines found in the original soft lens-fitting instructions, it suggests that the practitioner first measure the corneal diameter before selecting the diagnostic lens. Keratometry readings have replaced this point of the instruction set, however the effects of the horizontal visible iris diameter on the sagittal height of the anterior cornea must be considered.

Two patients may present to your office with the exact same corneal base curves. However, if the corneal diameters were measured, it would be found that patient A has a corneal diameter of 12.8mm while patient B is measured at 11.8mm. The diagram below demonstrates the above two corneas.
If the practitioner fitted all patients with the same standard contact lens, patient A would not be a successful fit. The lens for patient A would need to be selected with a steeper base curve and possibly a larger diameter. A case report is presented to illustrate the benefits of understanding the relationship between the iris diameter and sagittal height of the anterior cornea.

**Patient:** Patient DP was a nineteen-year-old male student attending Yale University and returned home to Portland for summer break. A complete ocular examination had been preformed by a local Ophthalmologist who then referred the patient on to a contact lens fitting specialist.

**Case History:** DP was in search of a contact lens that would stay on his eyes or that he would be able to tolerate a longer wearing time each day. Unsuccessful fits over the past two years at three different practices blemish the patient's history of contact lens attempts. The patient was a moderately high myope, which gave him the desire to be free of spectacles from time to time. Additionally, his involvement with the university drama department required the wearing of contact lenses during the majority of performances.

The most recent complete ocular exam was completed in June 1998. An unsuccessful contact lens fit prompted the referral to the specialist. At this time, the option of refractive surgery was also discussed but was not recommended due to the patient's age and his progressive myopia.

The first encounter with this patient was August 11, 1998. DP was wearing rigid gas permeable lenses that were tolerated for 3 hours before his eyes would "turn red and scratchy." Every attempt at soft lens wear was hopelessly abandoned due to lens displacement. Much frustration was felt by the patient and equally, I am sure, by the practitioner. At this exam the patient was currently not taking any prescription medications and denied any history of serious medical problems or recent illness. No allergies to medications or other sources were noted. During the previous ocular exam no unusual findings were reported.
The list of failed soft contact lens fits included Acuvue, Newvue, Focus, Sequence 2, Durasoft and CSI. Many of these lens modalities that were tried with more than one base curve. All of the lenses were reported to be uncomfortable and with any amount of wearing time the lenses would not stay on his eye. The referring physician dispensed the current rigid gas permeable lenses that the patient was wearing. The wearing time was greatly reduced due to the constant lens awareness of the lenses on his eyes. DP was following the proper care regime of cleaning the lenses after removal and storing the lenses in the conditioner overnight with the Boston Advanced care system.

The contact lenses measured: Materials-unknown (lt. blue)
OD: BC 41.00 / -6.00 / DIA 9.5 / OZ 8.3 / CT 0.13 / lenticulated
OS: BC 41.00 / -4.75 / DIA 9.5 / OZ 8.3 / CT 0.12 / lenticulated

Visual Acuity with contact lenses: OD 20/20
OS 20/20
OU 20/20+2

The spectacle refraction provided by the referring physician was:
OD: -7.00 sphere 20/20 (B.V.A.)
OS: -5.25 -0.25 X 160 20/20 (B.V.A.)

Keratometer measurements:
Horizontal Visible Iris Diameter
OD: 41.00@23/41.25@113 (0 distortion) 13.0 mm
OS: 41.25@144/41.37@54 (0 distortion) 13.0 mm

Present glasses: (2 years old)
Visual Acuity (with glasses)
OD: -6.25 -0.25 X 18 20/30
OS: -4.75 -0.25 X 147 20/25

Slit Lamp Exam: The rigid contact lenses were observed to ride low and due to an incomplete blink, the lenses usually maintained that position. Under a forced and complete blink the lens would return to a superior position, but then quickly drop to the lower corneal position. The lenses could be manually centered on the cornea, but then would drop to a lower position when released. A rapid break up of the tear film was noted subsequent to a complete blink.

The lenses appeared to be free of scratches and reasonably clean.

Ocular Health: The bulbar conjunctiva was injected (+1) OU, without chemosis. There was no indication of blepharitis or lid margin disease. The upper and lower
tarsal plates were free of papillae or injection. The tear film was free of debris with a normal tear meniscus height.

Fluorescein dye and cobalt blue filter revealed isolated (+1) superficial punctate keratitis (SPK) at the 4:00 and 8:00 positions on both corneas. The bulbar conjunctiva showed no staining. The contact lens demonstrated adequate tear exchange after a complete blink. The fluorescein pattern showed minimal central clearance along with 360° of bearing in the mid-periphery when the lens was centered in the geometric center of the cornea. The tear break-up time was calculated to be greater than ten seconds subsequent to the removal of the contact lenses.

**Assessment:** DP was not considered an optimal candidate for rigid gas permeable lenses due to his near spherical cornea. When the lens mass is excessive due to a high refractive error, as is exhibited with DP, and the cornea is essential spherical, a successful fit is difficult if not impossible. Lens impingement across the superior cornea makes centration of the rigid contact lens on the cornea a colossal task. Thus, the low riding contact lens can lead to an incomplete blink and symptoms of lens awareness or intolerance.

The SPK in the 4 and 8 o’clock corneal positions and conjunctival injection were likely due to exposure and desiccation secondary to the incomplete blink and may also have contributed to the symptoms of dryness.

DP’s horizontal visible iris diameter (HVID) was measured and it was found to be unusually large at 13.0mm. This was assumed to be the cause of the soft lens displacement. The large corneal diameter contributed to an extreme sagittal height value.

**Plan:** If DP were to wear contact lenses, it was felt that he would be most successful in soft contact lenses. A lens with a greater sagittal height value would be needed to accommodate the large horizontal visible iris diameter. DP was reluctant to agree to soft contact lenses since his past had been littered with unsuccessful fits. DP was educated as to the relationship of a larger horizontal visible iris diameter on the sagittal height of a cornea. It was also explained how this would cause the radius of curvature of his central cornea to be misleading. Most “stock” contact lenses would fit a cornea with the same radius of curvature, but a smaller horizontal visible iris diameter.

The first lens that was attempted was a Gentle Touch (WJ) 8.2 base curve / 14.5mm diameter. It was reported to feel the same as the previously trialed lenses and comfort was non-existent. Upon observation with the slit lamp, the lens was decentered laterally and eventually sloughed completely off of the cornea.
The next diagnostic lens was a Hydrasoft (Cooper Vision) 8.6 base curve / 15.0 diameter. There was adequate corneal coverage, however, the lens decentered slightly once again. These two trial lens sets clearly exhibited the reason for DP’s inability to wear soft contact lenses. His extreme sagittal height value could not be accommodated by the selection of current soft lenses used today.

It was determined that DP’s cornea would require special fitting considerations. A lens with a relatively large diameter and a steep base curve would need to be created. The initial lenses ordered were the CooperVision Hydrasoft XT, being the thin or extended wear model of the Hydrasoft. The parameters were as follows:

Hydrasoft XT  
OD: 8.3 / -6.50 / 15.0  
OS: 8.3 / -4.75 / 15.0

The thinner lens design would maximize the mid-peripheral oxygen transmissibility due to the moderate degree of myopic correction. The rigid gas permeable lens wear was discontinued and spectacles were worn until the arrival of the new soft contact lenses.

Two days later, on August 15, 1998, a brief slit lamp exam was performed in which it was found that the SPK was no longer evident. The new lenses were placed on the patient’s eyes revealing good centration and favorable movement of approximately 0.25mm from primary position with a blink. Visual acuity was 20/20 in each eye with the contact lenses. The patient was started on the AO Sept (Ciba) system for cleaning and disinfecting and was proficient with the instillation and removal of the lenses. His wearing time was started with 3 hours per day and to increase by 3 additional hours each following day.

**Follow-up Visits:** On August 18, 1998 the patient returned for a morning appointment wearing the prescribed Hydrasoft XT lenses. He reported that he was wearing the lenses for 10 hours each day with comfort and good vision. The visual acuity was 20/20 and did not change with the over-refraction. The lenses remained centered and continued to move freely in habitual blink response and with the push-up test. The corneas were free of corneal staining as well the lenses appeared clean and free of debris.

On August 25, 1998, DP returned for an afternoon appointment with the contacts on for 8 hours that day. His wear time had increased to 14-16 hours per day with no complaints of discomfort.

Visual acuity was:  
OD: 20/20 +2  
OS: 20/20  
OU: 20/15
Once again; the slit lamp examination showed that the lenses were centered with 1.0mm of coverage in all meridians. The lenses moved with 0.25-0.50 mm with blinking and moved freely with the push-up test. No signs of SPK were evident. At last the patient had arrived at a situation that provided good vision and comfort.

It is evident that had the original practitioner understood the influence the corneal diameter has on the ocular sagittal height, success would have been attained much sooner. Measuring the corneal diameter is an essential step to successful contact lens fitting. This measurement can be accomplished through a variety of techniques:

1. Hand held ruler
2. Slit lamp reticule

The first and simplest instrument is the ruler. This can be the standard PD ruler or other various measuring devices such as the one shown below. Half moon shapes of varying diameters can be placed inferiorly to the cornea to help facilitate the measurement of the horizontal visible iris diameter. The simplicity of the ruler is also found in the fact that it does not require any additional equipment or calibration.

![Corneal diameter measuring device](image-url)

Figure 4. Corneal diameter measuring device.
Next, there is a reticule that is used with a slit lamp. It tends to be the most accurate but it has the drawbacks of being difficult to calibrate and only works on certain slit lamps.

Videokeratography was not utilized in this study due to the expense of the equipment and the complexity of the procedure that is involved in the determination of the corneal diameter.

The purpose of this study was to develop an instrument that possessed the simplicity of the ruler and yet provided the accuracy of the slit lamp based reticule.

**METHODS**

Thirty-five third year optometry students volunteered to be subjects in this study of which 16 were females and 19 were males. Their ages varied from 23 to 35 years old. Each subject had both eyes tested with all three instruments:

1. Slit lamp and Reticule
2. Ruler
3. Irisometer.

The reticule was calibrated in the slit-lamp using a millimeter ruler placed at the distance where the eye would be measured. Once situated in the slit lamp, the patient was instructed to maintain fixation straight ahead. The eye was then focused in the slit lamp and the zero mark of the reticule was aligned with the one side of the limbus. The horizontal visible iris diameter was measured by reading the millimeter value at the point where the other side of the limbus coincided with the millimeter markings on the reticule. This procedure was then repeated on the fellow eye.

The ruler does not require calibration. It is placed against the patient's nose with the patient being instructed to look at the bridge of the nose of the examiner who is seated directly in front of the patient. The examiner then moves the measuring device horizontally until he finds a semi-circle that estimates the corneal diameter. The examiner should attempt to place the ruler as close to the cornea without contact, thus minimizing the amount of parallax error.

The Irisometer was developed and comprised of three parts; a modified caliper and two clear acrylic plates, each with a small vertical scribe marking that spanned the height of the individual plate. The caliper used in the study was a Craftsman brand, six-inch plastic caliper, which can be purchased at Sears. The caliper was then precisely measured using a Mitutoyo brand digital optical comparator.
Removing the two measuring ears with a band saw then modified the caliper. The debris from the cut was removed and the edge was polished with a Bridgeport vertical mill. Two 0.0860-inch diameter holes were drilled into the caliper at the location where the two measuring ears were removed. The two acrylic plates were made from 0.125-inch thick Lexan brand clear sheets. The plates were rough-cut using a band saw and then finished cut by using the vertical mill. A fixture was made to precisely hold the two plates at the same location on the vertical mill vice. Using an edge finder the digital readout (DRO) on the vertical mill was reset with respect to the proper coordinates. A 0.042-inch step was then cut into each plate. Two 0.086-inch holes were drilled in the acrylic plates at the same distance apart as that of the calipers. Using the values derived from the measurement of the calipers, the scribe marks were placed by making a very shallow cut (<0.005 deep). Using a 0.013-inch end mill did this. The plates were then turned on their sides and two, 0.118-inch diameter by 0.190-inch, deep holes were drilled for possible placement of a while LED. The tooling marks were then wet sanded from the critical viewing areas with a 4000 grit optical grade sanding paper. This was then polished using Maguire brand aircraft windshield cleaner. In order to see the scribe marks, the cuts were filled using black ink. After the ink dried, the plates were fastened onto the caliper using four Allen head cap screws and nuts. Various distances within reasonable iris diameters were set on the Irisometer. In order to verify the validity of the readings, the Irisometer was calibrated using the optical comparator. A small piece of rubber was mounted along the upper back surface to provide a comfortable contact area on the patient’s eyebrow region. The dimensions of the instrument are found in Diagram one.

The measurements were taken with the Irisometer by placing the top portion of the Irisometer on the eyebrow or forehead region of the patient. Then the caliper could be adjusted with a rotating dial until the two black lines were aligned at the limbus on both sides of the cornea. The exact measurement was then read from the caliper.

The same researcher took all measurements, thus allowing for direct comparison of all the data. All measurements were taken with the patient sitting looking in the straight-ahead position. Each instrument was used on each subject within minutes apart.

RESULTS

Raw data results are included in the appendix. The mean values, standard deviation and standard errors for all 70 eyes measured are presented in table 1. Using the Scheffe method of data analysis, results show that the differences in reading between Irisometer and the ruler were statistically significant at a P-value < .0001. Differences between the measurements taken with the ruler and the Reticule were also statistically significant at a P-value of .0063. The differences
in the measurements taken with the Irisometer and the Reticule were not statistically significant (P-value = .2123). Table 2 summarizes these results. Table 3 shows the mean values for all of the data. Graph 1 shows a bi-varient scatter gram with regression comparing the Reticule to the Irisometer, the graph shows a correlation of .722 and compared to a correlation of .676 between the Reticule and the ruler shown in graph 2. When comparing the accuracy of the ruler compared to the Reticule as shown in graph 3, the ruler tends to overestimate iris diameter. It also shows that compared to graph 4 (comparing the Irisometer to the Reticule) the ruler is less accurate than the Irisometer when comparing to the standard Reticule. Graph 4 also indicates that there is more chance that the reading you get from the Irisometer will be closer to the measurement obtained by the Reticule than the ruler. Graph 4 also indicates that the Irisometer slightly underestimates iris diameter.

**SUMMARY**

Measuring the corneal diameter, though it may seem trivial, can alert the practitioner to make a few simple adjustments to the diagnostic lens, thus arriving at a successful fit without numerous unsuccessful attempts. The Irisometer was developed to attempt to provide the accuracy of the slit lamp based reticule and the simplicity of the hand held ruler. The results of the study and the development of the Irisometer indicate that it is user and patient friendly and the instruments’ measurements were accurate. The Irisometer is also portable, light and does not require additional instruments such as a slit lamp. Subjects expressed that it was more comfortable not to have a light shining in their eyes. These results are sufficient evidence for the usefulness and importance of further development and production of the Irisometer for the use of the Contact Lens Fitting Practitioner.
**Table 1.** Mean values, standard deviation and standard errors for the 70 eyes measured in the study.

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Table 2: Scheffe for All data

Significance Level: 5%

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Table 3: Means Table for All data

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</table>
Graph 1. Bivariate scattergram with regression comparing the reticule with the Irisometer.

\[
\text{Reticule} = -3.34 + 1.266 \times \text{Irisometer}; R^2 = .722
\]

Graph 2. Bivariate scattergram with regression comparing the reticule and ruler.

\[
\text{Reticule} = -0.681 + 1.072 \times \text{Ruler}; R^2 = .676
\]
Graph 3. Histogram comparing the reticule to the ruler.

Graph 4. Histogram comparing the reticule to the Irisometer.
Diagram 1. Dimensions of the Irisometer
REFERENCES

1. Caroline PJ. Corneal sagittal height and soft contact lens design. Notes presented in contact lens class, Pacific University, 1998.