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# On the calculation of power from curvature of the cornea

THOMAS OLSEN

*From the Department of Ophthalmology, University of Aarhus, Aarhus Kommunehospital, DK-8000 Aarhus C, Denmark*

SUMMARY The theoretical basis for the calculation of corneal refractive power from anterior curvature is considered. It is shown that the power can be calculated with sufficient accuracy from one simple formula provided the refractive index of the 'cornea' is 1·3315. It is suggested that keratometer readings should be calibrated with this value in order to increase the accuracy in intraocular lens calculation.

In recent years the need for an exact estimation of the corneal power has arisen from the wish to control the refraction of the patient receiving an intraocular lens (IOL) implant.[1-4] Here we consider the premises of the calculation of corneal power from the anterior curvature of the cornea, as measured by the keratometer.

The principle of all current keratometers is to consider the cornea as a single refracting sphere so that the refractive power F can be calculated according to the formula for paraxial imagery:

$$F=\frac{1}{r}\cdot(n_a-n_o)\ \ldots\ldots(1)$$

where r=radius of curvature in meters, $n_o$=refractive index of air (=1·000), and $n_a$=assumed value of the refractive index of the 'cornea', which in fact is the cornea and the aqueous humour combined. The value of $n_a$ varies between various keratometers. Common values are 1·3375 (Haag-Streit, Bausch and Lomb), 1·336 (American Optical), 1·3333,[4] and 1·332 (Zeiss). A corneal curvature of 7·7 mm will thus read 43·83, 43·64, 43·29 or 43·12 D, respectively. Since an error of 1·0 D in the corneal power will cause an error of about 1·2 D in the calculation of IOL power, it is clear that the different calibration of the keratometers might cause considerable disagreement between the IOL power calculated by different investigators.

## Theory

The cornea is a two-surface system as shown in Fig. 1. The refractive power of each surface can be calculated according to formula (1), substituting for the respective refractive indices. When two surfaces of power $F_1$ and $F_2$ are combined, the following formula for the equivalent power $F_{12}$ apply:

$$F_{12}=F_1+F_2-d\cdot F_1\cdot F_2\ \ldots\ldots(2)$$

where d equals the distance 'reduced to air' between the two surfaces. (The reduced distance d is given by d=D/n, where D is real distance and n is refractive index.) In this way we obtain the formula for the total refractive power of the cornea (symbols shown in Fig. 1):

$$F=\frac{1}{r_1}\cdot(n_1-n_o)+\frac{1}{r_2}\cdot(n_2-n_1)-d\cdot\frac{1}{r_1}(n_1-n_o)\cdot\frac{1}{r_2}\cdot(n_2-n_1)\ \ldots(3)$$

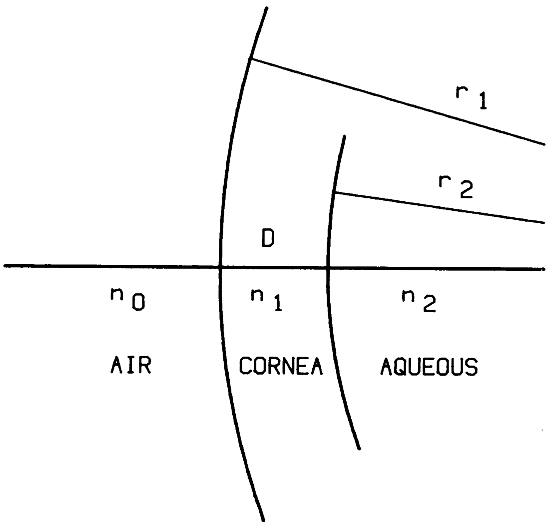


Fig. 1 *The optical components of corneal refractive power.*

Correspondence to Dr Thomas Olsen, University of Aarhus, Aarhus Kommunehospital, DK-8000 Aarhus C, Denmark.

where $n_o$=refractive index of air (=1·000), $n_1$=refractive index of cornea (=1·376), $n_2$=refractive index of aqueous humour (=1·336),[5] $r_1$=radius of curvature of anterior surface of cornea, $r_2$=radius of curvature of posterior surface of cornea, and d=reduced thickness of cornea. When the refractive indices are known, we have three unknowns: d, $r_1$, and $r_2$. If necessary d, or rather D, can be obtained from a clinical measurement of the corneal thickness, that is, by pachometry. However, the curvature of the posterior surface of the cornea, $r_2$, is not available from clinical methods and therefore has to be assumed.

As the first approximation we might assume the posterior curvature to relate to the anterior curvature with a constant factor k, so that

$$r_2 = k \cdot r_1 \ldots\ldots (4)$$

According to Gullstrand's exact schematic eye[6 7] the curvature of the anterior and the posterior surface of the cornea is 7·7 and 6·8 mm, respectively. A reasonable assumption might therefore be to assume k=6·8/7·7.

As the second approximation we might assume a constant thickness of the cornea, which in Gullstrand's exact schematic eye equals 0·5 mm. Inserting the constants, formula (3) now reduces to

$$F = \frac{1}{r_1} \cdot (0{\cdot}3307 - \frac{1}{r_1} \cdot (-0{\cdot}0000062)) \ldots (5)$$

The second part of formula (5) is a rather small value. If as the third and final approximation we assume the anterior curvature of the second part of formula (5) to be of the mean value (=7·7 mm), we obtain the following formula relating corneal power and anterior curvature around the mean value of the latter:

$$F = \frac{1}{r_1} (0{\cdot}3307 + 0{\cdot}0008)$$

or

$$F = \frac{1}{r_1} (1{\cdot}3315 - 1{\cdot}0000) \ldots\ldots (6)$$

In other words, the most likely value of $n_a$ in formula (1) is 1·3315.

## Reliability of a simple formula

With the present day access to computers there is no a-priori reason why the calculation of corneal power should be expressed in one simple formula. The corneal power might as well be calculated in a more

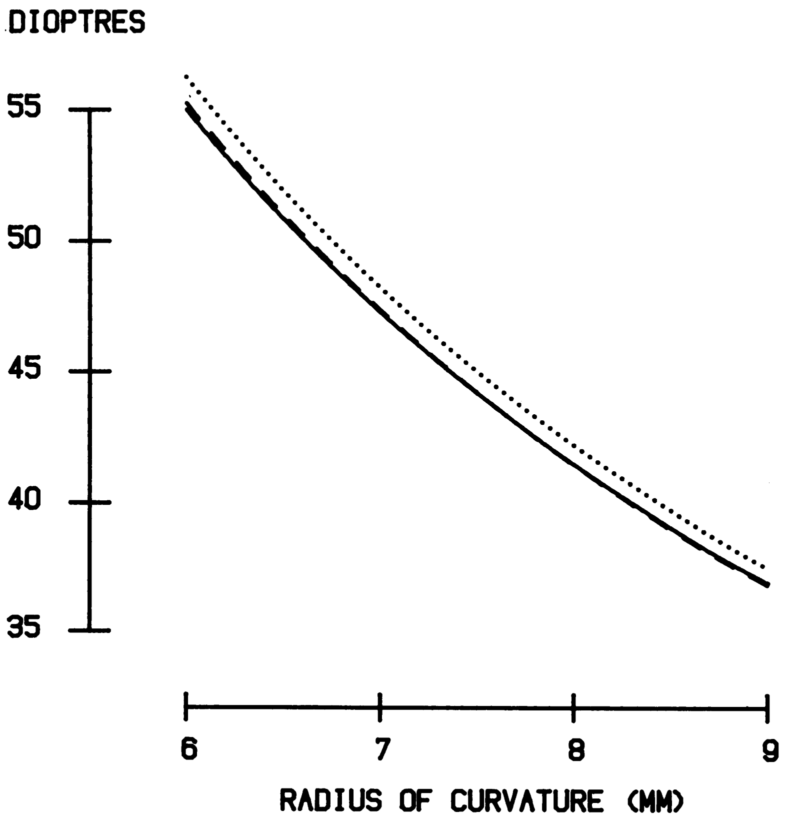


Fig. 2. *Corneal power calculated from anterior curvature by means of the simple formula (1) and an assumed refractive index of 1·3315 (continuous line), as compared with the power calculated according to the more accurate formula (5) (dashed line). Included for comparison is the reading of a current keratometer which assumes a refractive index of the 'cornea' of 1·3375 (dotted line).*

precise manner without unnecessary assumptions. Among the three assumptions made above, only the one regarding the posterior curvature is strictly necessary; the other assumptions are merely 'cosmetic'. Let us consider in some detail the possible errors of the assumptions made prior to formula (6).

The assumption on $r_1$ made from equations (5) and (6) implies that the true value of the corneal power will deviate from the value measured as the curvature deviates from the mean value. This has been illustrated in Fig. 2. Calculations show that the difference between the measured and the true value (measured value minus true value) is $-0{\cdot}08$, $-0{\cdot}04$, $-0{\cdot}01$, $0{\cdot}00$, $+0{\cdot}01$ D at $r_1=5{\cdot}0$, $6{\cdot}0$, $7{\cdot}0$, $8{\cdot}0$, and $9{\cdot}0$ mm respectively.

The influence of the corneal thickness on the corneal power is linear and very small. If, for example, for a standard cornea of curvature 7·7 mm and thickness 0·5 mm the thickness reduces to zero or doubles its value, the power reduces or increases by 0·1 D respectively. The error is greater for a more curved cornea.

For the standard cornea the posterior surface represents a minus lens of about $-6$ D. No clinical data are available on the variability of the posterior curvature of the cornea. Because the change in refractive index between the cornea and the aqueous is slight, the influence of the posterior curvature, or k in equation (4), is also slight. It can be calculated that to increase or decrease the power of the cornea by 0·5 D the value of k should increase or decrease by 9% respectively. The error is greater for a more curved cornea.

Hence, in conclusion it can be said that the corneal power can be calculated with reasonable accuracy (within 0·1 D) from one simple formula as defined in equation (1), provided the assumed refractive index is 1·3315. It is hoped that the use of this value may lead to greater standardisation in keratometry and in particular lead to more accurate predictions in intraocular lens power calculation.

**References**


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