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OPTICS OF KERATOPLASTY

By
H. LITTMANN,
Heidenheim, West Germany.

The optical conditions in keratoplasty will here be explained without going into an unnecessary amount of detail as regards surgical methods (Barraquer, J.; Katzin, M.) or mathematical problems (Kaplan, N.; Littmann, H.). Merely the results of the optical computation will be used to discuss the influence of measuring errors.
change in the curvature of the posterior corneal surface will be examined.

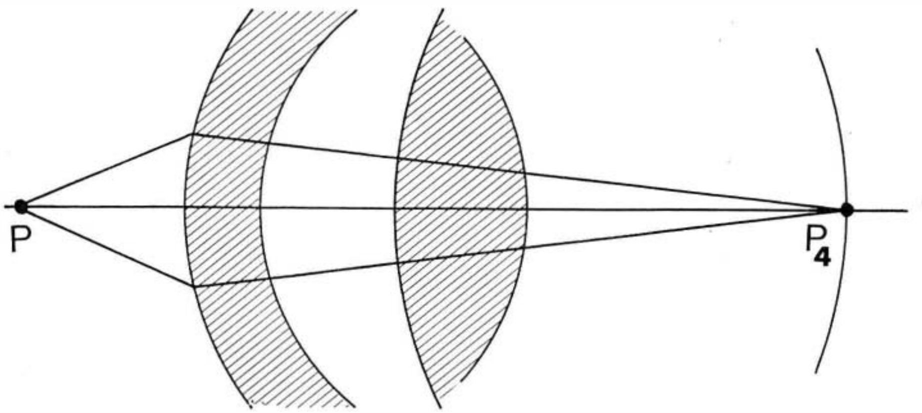

Fig. 1

Fig. 1 shows the principle of optical image formation on the fundus of a myopic eye. The far point P is the object, P4 its image on the fovea. The image is produced by refraction at the corneal and lens surfaces. The lens is assumed to be accommodation free. The various phases of this process of optical image formation will be discussed to begin with.

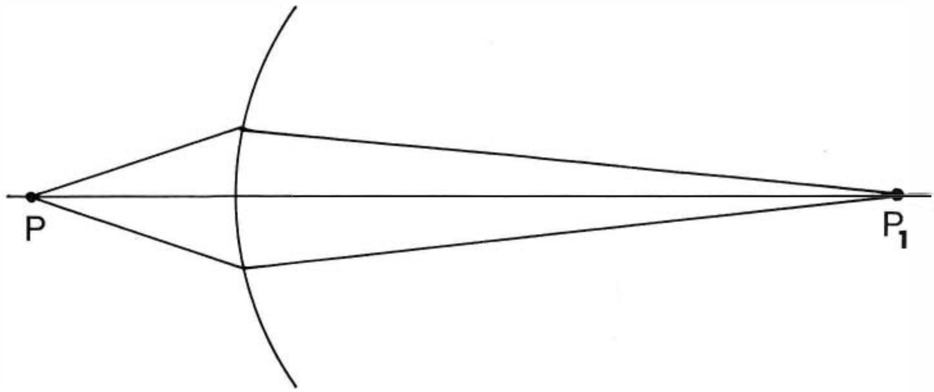

Fig. 2

Phase 1 **(Fig. 2)**: The light rays emanating from P are refracted by the anterior corneal surface in such a way that they are directed towards P1 after passing through the aforementioned surface. In other words: P_1 is the image of P formed by the anterior corneal surface.

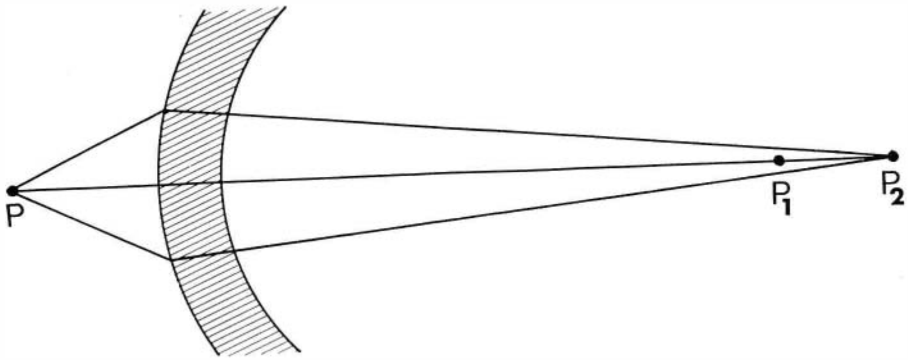

Fig. 3

Phase 2 **(Fig. 3)**: The light rays keep their direction in the interior of the cornea until they reach the back surface of the latter. Here the rays are refracted in such a way that they are directed towards P_2. P_2 is the image of P_1 formed by the posterior corneal surface or the image of P formed by the entire cornea.

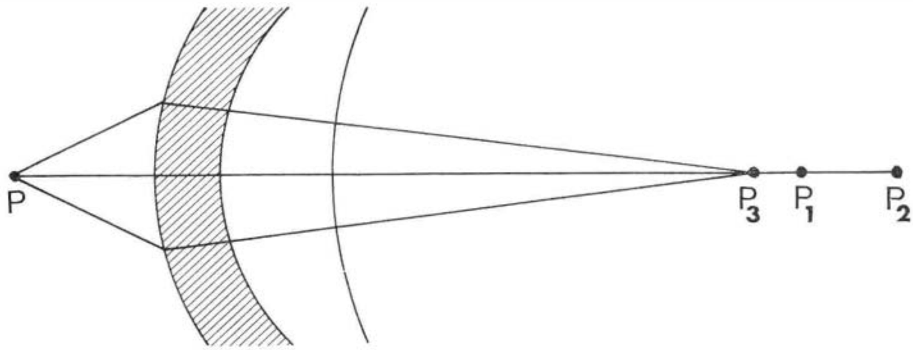

Fig. 4

Phase 3 (**Fig. 4**): The direction of the rays remains unchanged in the interior of the anterior chamber. The following change in direction occurs at the front surface of the lens, and the rays are directed towards P_3 in the interior of the lens.

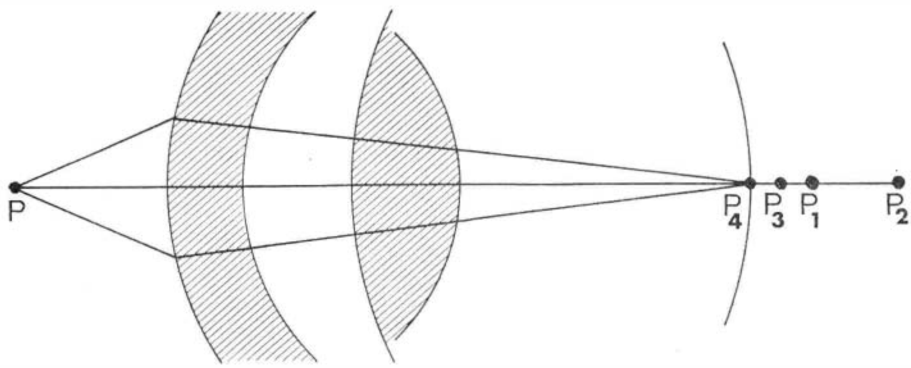

Fig. 5

Phase 4 (**Fig. 5**): The last refraction takes place at the back surface of the lens. In the interior of the vitreous body the rays are directed towards P_4 on the fovea. Thus the image PP_1 is formed by the anterior corneal surface. P_2, P_3 and P_4 are images of P_1 formed successively by the optically active surfaces in the eye.

To correct an ametropic eye by surgery it is therefore sufficient to change the anterior corneal surface so that it is not but infinity that is imaged at P_1. This also means that rays incident on the cornea parallel to the optical exis are directed towards P_1, as is shown in **Fig. 6 and 7.**

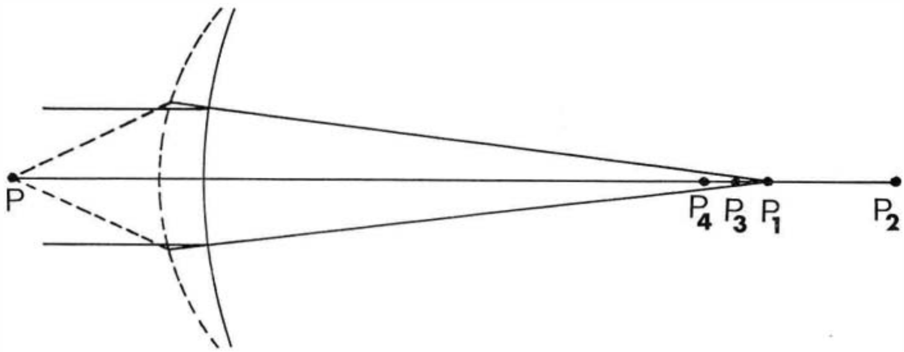

Fig 6

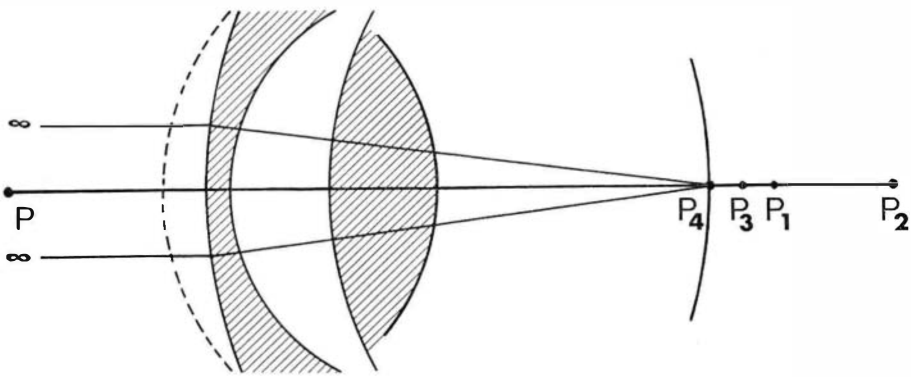

Fig. 7

In this example it is required to flatten the anterior corneal surface and make the cornea thinner in order to make the eye emmetropic. Fig 6 clearly shows that for computing the correction merely the anterior corneal surface and the thickness of the cornea must be considered, since the image at P_1 is automatically passed on via P_2 and P_3 to P_4 as is the case in the uncorrected eye. However, this applies only if the curvature of the posterior corneal surface and the remaining elements of the eye are not changed by surgery.

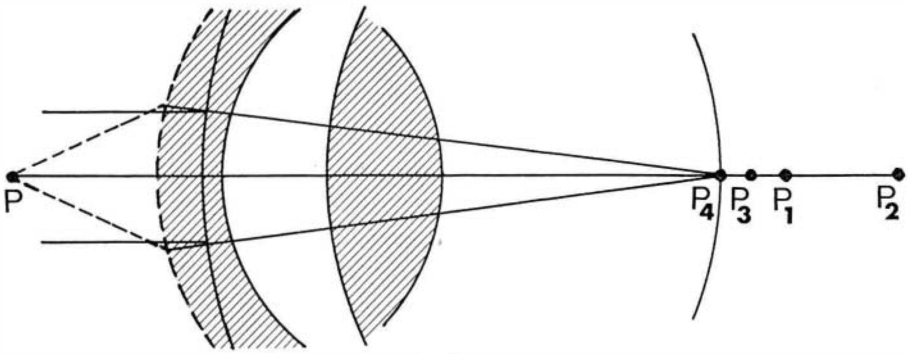

Fig. 8

Fig. 8 again shows the result. The correction is computed according to formula (1) (**Fig. 9**).

$$r_c = \frac{r_a}{\dfrac{r_a \cdot A}{1000 \cdot (n-1)} + 1} - \frac{n-1}{n}(d_a - d_c)$$

Fig. 9

The formula indicates the radius Rc which the front surface of the cornea must acquire in order to correct the ametropia A of the eye.

$A = \dfrac{1000}{1}$ (where 1 = the distance (in mm) between the far point and the vertex of the anterior corneal surface. Myopia: 1 negative, hypermetropia: 1 positive)

Ra = radius of the anterior corneal surface of the ametropic eye before surgery.

Da = thickness of the cornea before surgery.

Dc = thickness of the cornea after surgical correction.

N = refractive index of the corneal substance (= 1.376).

The formula in question applies exactly for any type of ametropia, i. e. both for refractive ametropia and axial ametropia. It also applies if the cornea is not thinner but thicker after surgical correction as, for example, with Barraquer's method of keratophakic surgery.

Up till now it was assumed that the posterior corneal surface was not change by surgery. Should however, contrary to expectations, the radius change, the more complex but also accurate formula (2a) **Fig. 10** would apply. The two auxiliary quantities z and w in that formula are defined formula are defined by (2b) and (2c).

$$r_c = \frac{n-1}{n} \cdot \frac{n - z(d_a - d_c) + w(n - z \cdot d_a) \cdot d_c}{z + w(n - z \cdot d_a)}$$

$$z = \frac{A}{1000} + \frac{n-1}{r_a}$$

$$w = \frac{n_2 - n}{n} \left(\frac{1}{rp_a} - \frac{1}{rp_c} \right)$$

Fig. 10

In addition to the data already used in formula (1) this formula includes:

N_2 = refractive index of the aqueous or vitreous body (N_2 = 1.336)
Rpa' = radius of the posterior corneal surface of the ametropic eye before surgery

Rpc = radius of the anterior corneal surface after surgical correction. If the radius is found to be unchanged by the operation, i. e. if

Rpa' = Rpc, then w = O and the formula (2^a) changes over into the simpler formula (1).

The radius of the posterior corneal surface can also be measured with an ophthalmometer. Measurement requires some experience, as the reflected mires are relatively dark. It must be considered for measurement that the ophthalmometer does not directly indicate the radius of the posterior corneal surface, since the coincidence position is affected by the optical power of the anterior corneal surface and the thickness of the cornea. The radius of the posterior corneal surface results from formula (3) **Fig. 11**

$$r_2 = \frac{n \cdot r_1^2 - 2(n-1) \cdot d \cdot r_1 + \frac{(n-1)^2}{n} \cdot d^2}{\frac{r_1^2}{R_2} + (n-1) \cdot r_1 - \frac{(n-1)^2}{n} \cdot d}$$

Fig. 11

where

R_2 = radius of the posterior corneal surface

R_1 = radius of the anterior corneal surface

R_2 = radius read of the ophthalmometer scale when the mires reflected by the posterior corneal surface are in coincidence.

N = refractive index of the corneal substance.

D = thickness of the cornea.

With the aid of formulas (1) and (2) the effect of the decisive magnitudes on the result can be computed. If the residual ametropia after surgery is to be smaller than ^{2}D., then the radius of the anterior corneal surface must be measured with an accuracy of 4% or 03 mm and established by surgery, the radius of the posterior corneal surface must be retained with an accuracy of 4% or 3 mm, and the refractive index of the corneal substance must be known with an accuracy of 1.1% 015.