Apparent Accommodation in Pseudophakic Eyes after Implantation of Posterior Chamber Intraocular Lenses: Optical Analysis

Mitsuru Nakazawa* and Kiyoshi Ohrsukif

The authors measured apparent accommodation in 39 pseudophakic eyes (31 patients) after implantation of posterior chamber intraocular lenses. The mean apparent accommodation was 2.01 ± 0.95 D. The authors also measured each patient’s pupillary diameter, anterior chamber depth, and corneal refractive power to calculate the factor that represents the depth of field. The authors found a significant correlation between apparent accommodation and depth of field. The correlation between apparent accommodation and calculated depth of field is statistically significant (r = 0.48, P < 0.005). Invest Ophthalmol Vis Sci 25:1458–1460, 1984

It long has been acknowledged that some aphakic patients have good near vision while wearing glasses with only their distance correction: The phenomenon has been called apparent accommodation.1-3 We4 previously reported that apparent accommodation also can be observed in pseudophakic eyes after implantation of posterior chamber intraocular lenses. In the previous study,4 we assumed that pupillary diameter is the major feature responsible for apparent accommodation, and depth of field. To confirm this speculation, we studied this relationship mathematically and optically.

Materials and Methods. The amplitude of apparent accommodation was measured in 39 eyes of 31 patients who underwent cataract extraction and posterior chamber lens (j-loop) implantation in the Tohoku Teishin Hospital between January 1981 and October 1982. All patients were operated on by one of us (K.O.). The subjects ranged in age from 42–90 years (mean age: 66 years). The method of measuring apparent accommodation was the same as previously described4: The near point for each patient was measured with the Ishihara near-point meter, and the far point was calculated from each patient’s refraction as determined by streak retinoscopy. We calculated the apparent accommodation in diopters in the pseudophakic eyes from the near and far points measured. All patients had normal ophthalmoscopic findings and anterior chamber depth. The pupillary diameter was measured with the Haab pupil meter under a slit-lamp microscope, which was magnified five times with constant illumination of 1,700 lux centered on the corneal surface. Anterior chamber depth was measured with the Haag-Streit anterior chamber depth meter. All patients understood the purpose and methods of this study and consented to undergo these measurements as mentioned above.

Depth of field consists of anterior depth of field (distance between N and Q in Fig. 1) and posterior depth of field (distance between Q and M in Fig. 1). Since the far point calculated from the patient’s refraction coincides with point Q in theory, we dealt with anterior depth of field in relation to apparent accommodation. The optical relationship between anterior depth of field and the optical system of the eye is shown in Fig. 2. Three following formulas concerning anterior depth of field can be described with geometrical optics as

\[
\frac{1}{f} + \frac{1}{f'} = P_T
\]  
(1)

\[
\frac{1}{f_t} + \frac{1}{f_t'} = P_T
\]  
(2)

\[
k = \frac{f_t - f'}{a} = \frac{1}{f_t'}
\]  
(3)

where \(f\) and \(f_t\) are the distance from the eye to Q and N, respectively; \(f'\) and \(f_t'\) are the distance from the eye to \(Q'\) and \(N'\), which are the conjugate points of Q and N, respectively; \(P_T\) is the total refractive power of the optical system, “\(a\)” is the actual optical aperture, or pupillary diameter in the eye; “\(k\)” is the diameter of the permissible blur circle AB, which is provided by the depth of focus.

The amount of anterior depth of field in diopters can be derived from formulas 1–3 as

\[
\frac{1}{f_t} - \frac{1}{f} = \frac{k}{a} \left( P_T - \frac{1}{f} \right)
\]  
(4)

Formula 4 can be also described as

\[
\frac{1}{f_t} - \frac{1}{f} = k \cdot \frac{1}{a} \left( P_C + P_L - d \cdot P_C \cdot P_L - \frac{1}{f} \right)
\]  
(5)

where \(P_C\) is corneal refractive power, \(P_L\) is the refractive power of the intraocular lens, and “\(d\)” is anterior...
chamber depth. If $k$ is constant, formula 5 shows that amplitude of the depth of field (diopter) is in proportion to $\frac{1}{a} \left( P_c + P_L - d \cdot P_c \cdot P_L - \frac{1}{f} \right)$. For convenience, we used $R$ to represent $\frac{1}{a} \left( P_c + P_L - d \cdot P_c \cdot P_L - \frac{1}{f} \right)$. Using $R$, formula 5 can be described as

$$\frac{1}{f} - \frac{1}{f_1} = k \cdot R \quad (6)$$

The actual amount of $R$ was calculated from each patient's data, as mentioned above. We studied the relation between apparent accommodation and $R$, because $R$ can be considered as representative of the anterior depth of field. The Student's t-test for statistical studies was used to show the significance level ($P$).

**Results.** Apparent accommodation in 39 pseudophakic eyes was $2.01 \pm 0.95$ D. We found a significant correlation between apparent accommodation and $R$ (Fig. 3). The correlation coefficient between them was 0.48 and was statistically significant ($P < 0.005$).

As reported in the previous study, we also found a significant correlation between apparent accommodation and the reciprocal of the pupillary diameter. The correlation coefficient between them was 0.46 and was also statistically significant ($P < 0.005$).

**Discussion.** In the present study, we examined the relation between apparent accommodation and depth of field. Although the actual far point coincides point M and the actual depth of field is composed of both anterior and posterior depth of field (distance between M and N in Fig. 1), it is difficult to measure the precise distance between point M and the eye clinically. Because the far point employed in this study was calculated from the patient's refraction determined by streak retinoscopy, it is the same point as point Q, and we dealt with anterior depth of field in relation to apparent accommodation. For convenience, we used $R$ to represent anterior depth of field, because anterior depth of field can be considered to be in proportion to $R$. This hypothesis can be justified when the diameter of the blur circle ($k$ in Formulas 3–5, AB in Figs. 1, 2) is constant. Although the actual amount of $k$ cannot be known precisely, we considered it constant in our patients because they had neither particular macular disease nor other retinal degeneration which might affect the resolving power of the retina.

The result obtained showed that a significant correlation exists between apparent accommodation and $R$ (Fig. 3); that is, apparent accommodation is almost proportional to $R$ by regression line analysis, because $0.22$ is almost negligible. That apparent accommodation is almost proportional to $R$ suggests that it is
highly related to anterior depth of field, which also is in proportion to R.

The correlation coefficient between apparent accommodation and R (0.48) was greater than that between apparent accommodation and the reciprocal of the pupillary diameter (0.46). That the correlation obtained by taking five factors into account increases the significance beyond that obtained with pupillary diameter alone supports the close relationship between apparent accommodation and depth of field.

Several authors\textsuperscript{5-9} have reported apparent accommodation in pseudophakic eyes after implantation with iris-supported lenses or iridocapsular lenses. Sugitani and co-workers\textsuperscript{5} and Huber\textsuperscript{7-9} have speculated that this phenomenon is related to depth of focus. Because depth of focus and depth of field are closely related (Fig. 1), the results obtained from the present study also support their speculations.

Key words: apparent accommodation, pseudophakic eye, posterior chamber intraocular lens, depth of field, depth of focus

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From the Department of Ophthalmology, Tohoku University School of Medicine,\textsuperscript{*} and the Department of Ophthalmology, Tohoku Teishin Hospital,\textsuperscript{†} Sendai, Japan. Submitted for publication: March 19, 1984. Reprint requests: M. Nakazawa, MD, Department of Ophthalmology, Tohoku University School of Medicine, 1-1 Seiryo-cho, Sendai, Miyagi 980, Japan.

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