Biomicroscopic Measurement of the Optic Disc with a High-Power Positive Lens

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PURPOSE. To compare the magnification properties of four different indirect double aspheric fundus examination lenses for clinical disc biomicroscopy.

METHODS. Experimental study in a model eye. The relationship between the true size of a fundus object and its image was calculated for each fundus lens for an ametropic range between $-12.5$ and $+12.6$ D using a slit lamp biomicroscope with adjustable beam length.

RESULTS. Equations for determining the correction factor $p$ (degrees per millimeter) were calculated for each fundus lens. The factor can be used in calculations to determine true optic disc size. The total change in magnification of the system from myopia to hyperopia was $-21.1\%$ to $+24.0\%$ (60-D lens; Volk Optical, Mentor, OH), $-12.9\%$ to $+16.2\%$ (Volk super 66 stereo fundus lens), $-13.2\%$ to $+13.9\%$ (Volk 78-D lens), and $-13.3\%$ to $+14.0\%$ (Volk super-field NC lens). When the fundus lens position was altered in relation to the model eye by $\pm 2$ mm under myopic conditions, the change in magnification of the system was $-4.3\%$ to $+5.7\%$ (60-D lens), $-4.6\%$ to $+6.1\%$ (66 stereo fundus lens), $-4.9\%$ to $+6.3\%$ (78-D lens), and $-5.9\%$ to $+7.8\%$ (super-field NC lens). In the hyperopic condition the change was $-2.7\%$ to $+3.6\%$, $-3.4\%$ to $+4.5\%$, $-3.6\%$ to $+4.8\%$, and $-4.5\%$ to $+6.0\%$.

CONCLUSIONS. The study has shown that the use of a single magnification correction value for each fundus lens may not be appropriate. These findings have important implications for the way in which calculations for determining the true optic disc size and other structures of the posterior pole are performed using indirect biomicroscopy. (Invest Ophthalmol Vis Sci. 2001;42:153–157)

In 1953, El Bayadi first examined the fundus with a plano-convex lens of approximately $+60$ D using the slit lamp biomicroscope, but the technique was not widely accepted because of aberration and difficulty of use. With the introduction of the double aspheric $60$-D lens in 1982 (Volk Optical, Mentor, OH), the technique started to gain popularity for routine stereoscopic examination of the posterior pole.

Since then, many attempts have been made to determine the true size of the optic disc with several types of high-power positive lenses using indirect ophthamoloscopy.

The advantages of this technique for determining the true optic disc size are the immediate availability of the results and the reduced costs in instruments and personnel compared with sophisticated techniques such as computer-based analysis of optic disc photographs (planimetry), scanning laser ophthamoloscopy, video-ophthalmography, and simultaneous stereo optic disc photography with digital photogrammetry. In addition, only a few ophthalmologists have access to this expensive equipment for routine clinical work, and optic disc measurement is usually performed at the slit lamp biomicroscope.

The purpose of this study was to compare four widely used high-power positive lenses regarding their magnification over a wide range of ametropia in the center of the image field, by using a slit lamp biomicroscope with adjustable beam length.

MATERIALS AND METHODS

Four commercially available double aspheric fundus lenses (60-D lens, 66 stereo fundus lens, 78-D lens, and super-field NC lens) manufactured by Volk Optical and a calibrated slit lamp biomicroscope (Haag-Streit 900; Bern–Koeniz, Switzerland) were used for this study. All lenses provide a stereoscopic view of the fundus and a wide field of view.

In the slit lamp biomicroscopy the observation system of the slit lamp is focused at a finite, short distance. The light from the fundus exits the eye parallel (i.e., from optical infinity); therefore, the slit lamp cannot be focused on the fundus. With the use of a high-power positive lens, a real inverted image of the fundus is formed in front of the slit lamp biomicroscope (toward the observer). For clear imagery, the slit lamp is focused on this image.

The size of this image as measured with the beam length on the slit lamp is dependent on magnification due to the patient’s eye (correction factor $q$: millimeters per degree), $9^{-12}$ magnification due to the condensing lens used to obtain the image (correction factor $p$: degrees per millimeter)$^{13}$ and the position of the condensing lens with respect to the eye, thus, for calculating the absolute dimensions of this image the total magnification of the system must be known.

To measure the change in magnification of the system with refractive error and variation in condensing lens position, a curved scale in the form of a quarter of a sphere was fitted with the help of an excimer laser on the fundus surface of a model eye (based on Gullstrand’s schematic eye), whereby the center of the spherical fundus, of the spherical scale and corneal lens are on the same line. This scale has to be curved because the optics of the slit lamp biomicroscope and fundus lens are designed for use with a curved field so that a flat scale only approximates to the retina in practice.

Distilled water, which has a refractive index similar to that of the media in the eye (1.336) was introduced in the anterior and vitreous chambers. In this situation the equivalent power of the model eye is $+59.4$ D. By means of a screw ruled in micrometers, the vitreous chamber depth can be precisely varied to produce axial ametropia.

Experimental Procedure

The fundus object was viewed with each fundus lens as in a routine examination of the optic nerve head. The instruments were aligned perpendicularly to the model eye’s cornea and the fundus object was brought into focus by moving the biomicroscope away from the condensing lens until a sharp image of the fundus object was provided into the center of view. Figure 1 shows the optical diagram of the experimental setup.

A narrow slit beam, with width maintained at 0.2 mm, was progressively reduced in size from 8 mm until it coincided with the...
diameter of the fundus object. The beam length was then recorded from the millimeter scale at the top of the instrument. Because the slit lamp beam length is calibrated in 0.1 mm, the reading was judged to the nearest 0.05 mm. After each reading, the millimeter scale was reset to 8 mm.

Measurements were taken with the vitreous depth of the model eye set at values corresponding to a range of ocular refraction from −12.5 to +12.6 D. The pupil width was 8.0 mm in diameter. For each fundus lens, three measurements were obtained at each value of the ametropia setting. This process was repeated at another session for each fundus lens, and the 95% confidence intervals for repeatability were calculated.

The fundus lens correction factor $p$ was then determined according to the formula:

$$p = \frac{K}{17.453} \cdot \frac{t}{s}$$

where $K$ is the ametropia of the eye + equivalent power of the eye, $t$ is the fundus object size (the diameter), and $s$ is the measured size of the fundus object’s diameter on the slit lamp biomicroscope.

To investigate the change in magnification of the system with variation in condensing lens position, measurements of the fundus object size were obtained as described when the fundus lens position was altered by ±2 mm to the model eye’s cornea under myopic and hyperopic conditions.

**RESULTS**

**Fundus Lens Correction Factor**

Figure 2 shows the determined values of correction factor $p$ for each fundus lens. With the 60-D lens, the fundus lens correction factor is constant over an acceptable range of ametropia (−12.5 to +12.6 D). The value of $p$ for the 66 stereo fundus lens, 78-D lens, and super-field NC lens is constant from −5 to +5 D. In the presence of high refractive error, these fundus lenses show a linear relationship between correction factor $p$ and ametropia, which can be determined from linear regression analysis. The reason for this, compared with the 60-D lens, lies in the difficulty of making the focal plane of the condensing lens coincide with the first principal plane of the eye in the presence of a high refractive error. It means that in a normal clinical setting at the slit lamp biomicroscope with these fundus lenses (66-D, 78-D, and super-field NC lenses), in presence of a high refractive error the image obtained may appear to be focused adequately to make a measurement with the slit beam, when in fact the focal plane of the condensing lens is not exactly at the first principal plane of the examined eye.

The corresponding mean values for $p$ for each fundus lens are given in Table 1. Ophthalmologists can determine the $p$ for the 66 stereo fundus lens, 78-D lens, and super-field NC lens for an ametropic range over ±5 D from regression line equations as shown in Table 1. These regression line equations give an estimate of the fundus lens correction factor $p$ for any degree of ametropia. The 95% confidence intervals for repeated measurements of $s$ are also shown in Table 1. These are expressed as percentages of $s$ and are within acceptable limits.

**Magnification**

Figure 3 shows the total change in magnification of the system for each fundus lens. The minimum magnification was $-0.88 \times$ (60-D lens), $-0.83 \times$ (66 stereo fundus lens), $-0.80 \times$ (78-D lens), and $-0.64 \times$ (super-field NC lens). The maximum magnification was $-1.38 \times$ (60-D lens), $-1.10 \times$ (66-D lens), $-1.05 \times$ (78-D lens), and $-0.84 \times$ (super-field NC lens). The minus sign indicates an inverted image. The change in magnification therefore was $-21.1\%$ (60-D lens), $-12.9\%$ (66-D lens), $-13.2\%$ (78-D lens), and $-13.3\%$ (super-field NC lens) for myopia and $+24.0\%$, $+16.2\%$, $+13.9\%$, and $+14.0\%$ for hyperopia.
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Slit Lamp Biomicroscopy

The interindividual variability in optic disc size is morphogenetically and pathogenetically important. Therefore, for clinical purposes, it is usually sufficient to know whether the optic disc is abnormally large, medium, or abnormally small.

With the help of the fundus lens correction factor \( p \) (see Table 1), ophthalmologists can determine the true size of the optic disc \( t \) according to Littmann’s formula:

\[
t = pqs^q
\]

where \( s \) is the optic disc diameter measured at the slit lamp biomicroscope, which must be calibrated before the measurement, and factor \( q \) is the relationship of the real diameter of the optic disc measured in millimeters to the angular diameter, with which the optic disc is reflected through the optical system of the eye in its exterior space. It is a variable dependent on the optical dimensions of the patient’s eye and not the fundus imaging system. Several methods are available for determining the ocular factor \( q \) in millimeters per degree for a human eye based on ametropia and keratometry, ametropia and axial length, and axial length only.

Another accurate method to determine the true optic disc size is according to the formula:

\[
s = tm^{16}
\]

in which \( m \) is the total linear magnification of the system. It can be determined according to the formula:

\[
F = D - R + 66.6
\]

where \( F \) is ametropia of the examined eye. The \( + \) figure is the equivalent power of the eye. It can be calculated by \( F_p(1 - 0.001 \cdot vF) \), where \( v \) is the vertex distance (positive) from the back surface of the spectacle correction of power \( F_p \) to the cornea.

A, ametropia of the examined eye. The \( + \) figure is the equivalent power of the eye. It can be calculated by \( F_p(1 - 0.001 \cdot vF) \), where \( v \) is the vertex distance (positive) from the back surface of the spectacle correction of power \( F_p \) to the cornea.

The change in magnification was

\[
\begin{align*}
\text{Volk 60-D lens} & : 3.04 \pm 0.04 \text{ (mean \pm SD)} \\
\text{Volk 66 stereo fundus lens} & : 3.56 \pm 0.06 \text{ (mean \pm SD)} \\
\text{Volk 78-D lens} & : 3.69 \pm 0.06 \text{ (mean \pm SD)} \\
\text{Volk super-field NC lens} & : 4.61 \pm 0.03 \text{ (mean \pm SD)}
\end{align*}
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\[
\begin{align*}
\text{Range of Factor p (deg/mm)} & : 2.96-3.08 \\
\text{95% Confidence Interval for Repeated Measurements of s (%) } & : +3.24 \text{ to } -3.67 \\
\text{Range of Ocular Refraction Investigated (D) } & : -12.5 \text{ to } +12.6
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Figure 4 shows the change in magnification of the system for each fundus lens when the lens position was altered \( \pm 2 \) mm to the model eye’s cornea. The magnification of the system was \(-0.84\times\) (60-D lens), \(-0.79\times\) (66-D lens), \(-0.76\times\) (78-D lens), and \(-0.60\times\) (super-field NC lens) when the condensing lens was too close, and \(-0.93\times\) (60-D lens), \(-0.88\times\) (66-D lens), \(-0.85\times\) (78-D lens), and \(-0.69\times\) (super-field NC lens) when the lens was too far away from the eye under myopic conditions. The change in magnification was \(-1.43\times\) (60-D lens), \(-1.15\times\) (66-D lens), \(-1.10\times\) (78-D lens), and \(-0.89\times\) (super-field NC lens) when the lens was too close, and \(-1.34\times\) (60-D lens), \(-1.06\times\) (66-D lens), \(-1.01\times\) (78-D lens), and \(-0.80\times\) (super-field NC lens) when the lens was too far away under hyperopic conditions.

In practice, this degree of error should not arise if the operator is careful when positioning the condensing lens, but it serves to demonstrate the possible error caused by incorrect lens positioning when large refractive errors are present.

**DISCUSSION**

The interindividual variability in optic disc size is morphogenetically and pathogenetically important. Therefore, for clinical purposes, it is usually sufficient to know whether the optic disc is abnormally large, medium, or abnormally small.

With the help of the fundus lens correction factor \( p \) (see Table 1), ophthalmologists can determine the true size of the optic disc \( t \) according to Littmann’s formula:

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where \( s \) is the optic disc diameter measured at the slit lamp biomicroscope, which must be calibrated before the measurement, and factor \( q \) is the relationship of the real diameter of the optic disc measured in millimeters to the angular diameter, with which the optic disc is reflected through the optical system of the eye in its exterior space. It is a variable dependent on the optical dimensions of the patient’s eye and not the fundus imaging system. Several methods are available for determining the ocular factor \( q \) in millimeters per degree for a human eye based on ametropia and keratometry, ametropia and axial length, and axial length only.

Another accurate method to determine the true optic disc size is according to the formula:

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where \( F \) is ametropia of the examined eye. The \( + \) figure is the equivalent power of the eye. It can be calculated by \( F_p(1 - 0.001 \cdot vF) \), where \( v \) is the vertex distance (positive) from the back surface of the spectacle correction of power \( F_p \) to the cornea.

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where $F_e$ is the equivalent power of the eye, $A$ the ametropia of the eye, $F_c$ the power of the condensing lens, $e$ the position of the first principal plane of the eye, and $d$ the working distance of the condensing lens. The minus sign indicates an inverted image. It is not possible to collect this amount of data in clinical practice, and thus the true optic disc size has to be estimated on the basis of fewer, easily obtained variables, as has been described.

It is equally important that the slit lamp and fundus lens be aligned correctly in front of the patient’s cornea and the optic disc be centered in the image field to maximize the repeatability of the experimental setup. Figures 2 and 4 show that the measurements are highly dependent on the distance of the condensing lens from the eye, particularly in presence of a high refractive error. In clinical disc biometry, the degree of error can be minimized if the operator is careful when positioning the slit lamp biomicroscope and condensing lens and if the total magnification of the system is taken into consideration as described.

If the true minimal and maximal diameters of the optic disc and cup are known, ophthalmologists can determine the optic disc, cup, and neuroretinal rim areas according to the formula of an ellipse.\(^\text{17}\) This is especially important in the identification of optic discs with glaucomatous optic neuropathy.\(^\text{18}-\text{19}\)

The slit lamp biomicroscopic measurement of the optic disc diameter, using a high-power positive lens, shows an acceptable intraobserver and interobserver variability in routine clinical work compared with other sophisticated and time-consuming methods for clinical disc biometry.\(^\text{2,5,20,21}\)

Previous studies have investigated biomicroscopic measurement of the optic disc with different indirect double aspheric fundus examination lenses,\(^\text{4}-\text{6}\) by comparing the optic disc diameter measured at the slit lamp biomicroscope and its true size obtained by photogrammetry or Heidelberg Retina Tomograph, (Heidelberg Engineering, Heidelberg, Germany) to assess a conversion factor or equation for each fundus lens. A single conversion factor or equation can provide only a rough estimation of the optic disc size (see Fig. 3).\(^\text{16}\) Spencer and Vernon\(^\text{17}\) showed that according to a single conversion factor, the Volk 78-D lens gives larger measurements of the optic disc than photogrammetry (using ametropia and keratometry)\(^\text{22}\) by 0.41 mm.

A potential problem of these studies is that the obtained measurements were analyzed by using correlation coefficients.\(^\text{4}-\text{6}\) However, in the analysis of measurement method comparison data, neither the correlation coefficient nor techniques such as regression analysis are appropriate.\(^\text{14,23}\) The correlation coefficient measures the strength of a relation between two variables, not the agreement between them. Perfect agreement is attained only if the points of measurements lie along the line of equality, but perfect correlation is attained if the points of measurements lie along any straight line.\(^\text{23}\)

The fundus lens correction factor $p$ (see Table 1) allows slit lamp biomicroscopic measurement of the real optic disc size for any degree of ametropia and makes biomicroscopic measurements with different fundus lenses comparable. Furthermore, the factor $p$ can be used in the measurement of other structures of the posterior pole, such as retinal or choroidal tumors, and in the assessment of macular degeneration, by measuring the extent of the disease and its distance from the center of the foveal avascular zone. This would be of particular importance when comparing the morphometric characteristics of a fundus landmark of interest between individuals with regard to diagnosis and therapy. Therefore fundus landmarks should be measured in absolute size units (millimeters), instead of using the interindividually variable disc diameter as a measurement unit. It should be considered, however, that the ocular correction factor $q$ can be used with sufficient accuracy within ±20° of the optical axis.\(^\text{9,12}\)

The present study had the advantage of using the ideal optical condition of a model eye. The purpose of our next study will be to investigate the potential of this technique for clinical disc biometry, in comparison with magnification-corrected photogrammetry of the optic disc.

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**References**