A New Fundus Camera Technique to Help Calculate Eye-Camera Magnification

A Rapid Means to Measure Disc Size

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Objective: To find a simple means for calculating eye-camera magnification to permit estimation of true retinal object size from a retinal photograph.

Methods: The position of the focusing knob on 3 different retinal cameras (TRC-50F and TRC-50X; Topcon America Corp, Paramus, NJ; and the CR6-45NM Nonmydriatic Retinal Camera; Canon Inc, Tokyo, Japan) was measured during optic nerve photography and correlated with the refractive error, or spectacle refraction, of the subject (N=11 for each camera).

Results: A strong correlation was found between focusing knob position and spectacle refraction for each of the 3 cameras tested (r = 0.96, r = 0.99, and r = 0.97, respectively).

Conclusions: The focusing knob position reflects the spectacle refraction of the eye being photographed, and spectacle refraction is known to correlate well with eye-camera magnification. Therefore, focusing knob position can be used to help calculate eye-camera magnification and, hence, true retinal object size.

Clinical Relevance: The true size of the optic nerve head is important for the diagnosis of glaucoma from a retinal photograph. This technique is a simple means to calculate optic nerve head size, which may be especially useful in mass retinal photographic screening programs.

Arch Ophthalmol. 2003;121:707-709

The diagnosis of glaucoma from a fundus photograph may be aided by knowing the true size of the optic nerve head and the true area of the nerve tissue. However, determining scale from photographs taken with a fundus camera is a challenge. Currently, the best method for estimating true optic disc size from a retinal photograph involves discovering the camera constant (or camera magnification), obtaining an ultrasonogram of the eye to ascertain its axial length, then using these values to calculate the image magnification, per the 1992 article by Bengtsson and Krakau. Their article also described 2 other formulas for calculating image magnification; the first uses the refractive error, or spectacle refraction, of the eye, and the second uses the principal point refraction of the eye in addition to the corneal curvature deviation from normal, a technique originally described by Littman. Although none of these methods provide an exact solution to the image magnification problem, each technique does offer a good estimate of image magnification and, hence, optic disc size. All of these procedures are somewhat tedious because supplemental testing of the subject is required to derive the eye-camera magnification factor. A simpler means to elucidating this image magnification calculation would be desirable, especially in view of the potential some newer nonmydriatic digital cameras have for population-based mass screening for glaucoma.

The optical design of the fundus camera is similar to that of the indirect ophthalmoscope. A light source within the camera illuminates the retina. The luminous retinal structures are projected through the pupil and then through the front lens or ophthalmoscopic lens of the camera where an image (the so-called first aerial image of the fundus) is formed. Because the ophthalmoscopic lens of any given camera is a constant, and the distance from the eye being photographed is fixed, the position of this first aerial image in relation to the lens can be seen as a function of the optical error or spectacle refraction of the eye (Figure 1). This first aerial image is then brought into focus on the film plane by means of the focusing mechanism (often a knob located on the side of the camera which is attached to the...
camera body to adjust the distance between the camera objective and the film plane\textsuperscript{4}). It is reasonable that the position of this focusing knob will reflect the spectacle refraction of the eye. This study tests this hypothesis using 3 different fundus cameras.

**METHODS**

The study was approved by an institutional ethics committee. Subjects were recruited from among our friends, colleagues, and the clinical practice of one of us (M.G.Q.), and care was taken to recruit subjects with a range of refractive errors. Subjects were photographed with a fundus camera, and the position of the focusing knob was recorded. For the first camera, the TRC-50F (Topcon America Corp, Paramus, NJ), a 180° protractor was affixed to the focusing knob, and the position of the knob, as measured against a fixed point marked on the camera body, was recorded as the degree number marked on the protractor (N=11). For the other 2 fundus cameras, the TRC-50X (Topcon America Corp) (N=11) and the CR6-45NM Non-mydriatic Retinal Camera (Canon Inc, Tokyo, Japan) (N=11), a photocopy of a 150-mm ruler was taped to the circumference of the focusing knob. A reference mark was then made on the camera body just above the focusing knob so that a measure of the position of the knob on the ruler scale could be made in millimeters (Figure 2). This measurement was recorded for each photographed subject.

Subjects photographed with the Topcon cameras had their pupils dilated with 1 drop of 0.8% tropicamide hydrochloride and 5% phenylephrine hydrochloride before being photographed, whereas those photographed with the CR6-45NM did not have their pupils dilated. Additionally, photographs taken with the Topcon cameras were done using a red-free filter and a 20° field (these maneuvers were felt to best minimize depth of field and, hence, minimize errors in focusing knob position). Photographs taken with the CR6-45NM were performed at the standard wide-angle 45° field with no special filter in place. The position of the camera focusing knob was then correlated with each patient’s spectacle refraction using standard computer statistical software (Excel; Microsoft Corp, Redmond, Wash).

**RESULTS**

The position of the focusing knob on all 3 cameras correlated highly with the refractive error of the eye being photographed ($r=0.96$ for the TRC-50F; $r=0.99$ for the TRC-50X; and $r=0.97$ for the CR6-45NM) (Figure 3).

**COMMENT**

The results show a previously unreported, highly significant correlation between the position of the focusing knob and the spectacle refraction of the eye for all 3 fundus cameras. In other words, once the camera is appropriately positioned and focused on the retina, the position of the focusing knob reflects the absolute spherical equivalent refraction of the subject being photographed. Given that spectacle refraction can be incorporated into a formula that provides a good approximation of eye-camera magnification, the strong correlation of the focusing knob position with the subject’s spectacle refraction would permit eye-camera magnification to be calculated for any retinal photo-

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**Figure 1.** A simple schematic showing myopic (M), emmetropic (E), and hyperopic (H) retinal objects forming their respective aerial images (M’, E’, and H’) inside the camera. The distance between the camera objective lens and the film plane is altered with the focusing knob to bring the desired image into focus on the film plane.

**Figure 2.** A photograph of the knob position measuring tool (vernier scale) as used on the TRC-50X camera (Topcon America Corp, Paramus, NJ) and the CR6-45NM Non-mydriatic Retinal Camera (Canon Inc, Tokyo, Japan).

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\textsuperscript{4} Varma et al.\textsuperscript{4} used an eye-camera magnification correction factor based solely on the refractive error of the patient to determine optic nerve size in their population-based glaucoma screening study. However, they were obliged to obtain refractive error measurements with supplementary testing. The technique that we are describing no longer requires that this additional measurement of refractive error be done. Hence, in any mass screening programs, such as that of Varma et al, using this technique would obviate the separate step of obtaining the spectacle refraction; instead, the position of the focusing knob could be used to determine the spectacle refraction to help in calculating the eye-camera magnification.

Our results also confirm that there is a linear relationship between focusing knob position and the change in spectacle refraction.\textsuperscript{5} This is in agreement with the well-known optometer principle that, in short, permits continuous linear variation of power in refracting instruments, including automatic refractometers and lensometers.\textsuperscript{6} In this way, the fundus camera can be regarded as a refracting instrument. Interestingly, the linear relationship has been previously noted by Bengtsson.
In summary, the advantage of this technique can readily be seen when contemplating any population-based mass screening programs for glaucoma because all the information required to calculate optic nerve size is collected at the same sitting. Simply recording the focusing knob position (which reflects the refractive error of the patient), knowing the camera constant (representing its magnification), and incorporating this information into a formula (such as one previously derived by Bengtsson and Krakau\textsuperscript{2} for calculation of eye-camera magnification), will permit a good estimate of optic nerve size. Preliminary results comparing optic nerve head size calculations performed with this technique to optic nerve size calculations obtained with the Heidelberg scanning laser ophthalmoscope show a good correlation between the 2 techniques.\textsuperscript{9} A larger study comparing the 2 techniques is in progress.

Submitted for publication May 15, 2002; final revision received December 2, 2002; accepted December 26, 2002.

This study was presented as a poster at the Association for Research in Vision and Ophthalmology annual meeting, April 30 to May 3, 2000, Ft Lauderdale, Fla.

We thank Olga Overbury, PhD, for her assistance in the statistical analysis of the data.

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