DEFECTS OF VISION THROUGH APHAKIC SPECTACLE LENSES*†

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By the use of a series of scale diagrams an attempt is made to explain the following:

- (1) How the prismatic effect at the edge of the strong-plus spectacle lens creates the so-called "ring scotoma" of cataract spectacle lenses.
- (2) How this "ring scotoma" restricts the visual field of the spectacle-corrected aphakic.
- (3) How the peripheral prismatic effect, "ring scotoma", and the smallness of the spectacle lens refracting area altogether destroy the normal panorama of the visual field accomplished by wide ocular excursions, and how they severely limit the field of view for central vision through the strong-plus fixed forward lens.

As in Fig. 1, the normal eye has an effective power of approximately $+58.6$ D. The average power of the cornea is $+42.5$ D. This leaves $+16.1$ D. in effective power for the crystalline lens of the eyeball during distance vision. A pencil of parallel rays from an object point source in infinity on the visual axis will be brought to focus at a point on the retina as is shown here.

FIG. 1.—Focusing power of normal eye.

FIG. 2.—Blurring of focus in aphakic eye.

Remove the crystalline lens as in Fig. 2, and these rays will not be point focal on the retina. There is a state of marked hyperopia and the focal plane is theoretically 6.4 mm. behind the eye. The focus on the retina is extremely blurred in average aphakia.

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Fig. 3 shows that from object point sources at infinity, the sizes of the central and peripheral pencils of rays are determined by the size of the pupil. The peripheral pencils of rays can be considered as being bent only by the cornea in the simple state of aphakia. We may now omit the "nodal point" concept of ray tracing, which, in my opinion, has caused confusion in studying the forthcoming dynamic situations.

Place a high-plus spectacle lens of proper power 8 mm. in front of the eye, fixed to the head by a spectacle frame, and the central pencil will be point focal on the retina once more for the eye in primary fixation, as in Fig. 4.

FIG. 3.—Blurred focus planes of central and peripheral rays in aphakic eye.

FIG. 4.—Effect of high-plus spectacle lens on central rays in aphakic eye.

The visual field of the normal eye is well known; the visual field of the uncorrected aphakic eye is severely blurred but to maximum stimulus it can be demonstrated, as in Fig. 5, to be almost as large as the normal field.

FIG. 5.—Visual field of aphakic eye without correction.

Consider a pencil of rays 60° temporal to fixation; the focus is extremely blurred on the retina, as in Fig. 6.

Place a high-plus spectacle lens of proper power tilted 60° so that the axis coincides with the 60° pencil, and the pencil of rays will be in focus on the retina, as in Fig. 7.

FIG. 6.—Blurred focus plane of rays at 60° temporal to fixation in aphakic eye.

FIG. 7.—Effect of high-plus spectacle lens placed to one side on the peripheral rays as in Fig. 6.

In spectacle-corrected aphakia, the lens does not tilt 60° to see peripherally as is shown here. The spectacle lens is fixed to the head and is stationary in front of the mobile eye. The dynamic situation of an eye moving to see peripherally behind an immobile high-plus spectacle lens creates for the aphakic patient many severe, both transient and permanent problems, the worst of which will be analysed here.

Consider the ray at 62° from fixation (Fig. 8, opposite). Because of the peripheral prismatic effect of this high-plus spectacle lens, this pencil of rays is bent about 12 to 15° . Thus, the 62° pencil from in front of the spectacle lens is not seen by the primary fixing eye, as in Fig. 9 (opposite).

How much ray bending power does a high-plus spectacle lens have at its periphery? The parallel rays from an axial source in infinity are brought to focus at the focal point, and the ray-bending power increases progressively towards the lens periphery. A prism bends rays towards the base of the prism, and a high-plus lens can be considered as multiple prisms of increasing power from the optical centre to the lens periphery. These theoretical prisms are *base* towards the optical centre.

The prismatic effect in prism dioptres can be calculated by the Prentice Rule. A +1 dioptr lens 10 mm. peripheral to the optical centre will bend an axial parallel ray one prism dioptr. A +10 dioptr lens 10 mm. from the optical centre will bend rays 10 prism dioptres. If a +12 D spherical lens is 22 mm. in radius, the ray-bending power at the lens periphery will be $22 \times 1.2 = 26.4$ prism dioptres. Since 2 prism dioptres equals approximately one arc degree, 26.4 prism dioptres = approximately 13.2 arc degrees.

FIG. 8.—Peripheral rays at 62° achieving blurred focus plane.

FIG. 9.—Peripheral rays at 62° bent by spectacle lens in normal position in front of the eye so that they are not seen at all.

This explains why in Fig. 9, the 62° ray is bent approximately 13.2° and is not seen by the eye. For the primary fixing aphakic eye in Fig. 10, this ray-bending power creates a completely blind somewhat circular area which starts at about 51° from fixation and extends to about 64° . Remember that vision is unrefracted extending from the temporal 64° to the most peripheral portion of the visual field at 85° . For

FIG. 10.—Creation of circular blind area at edge of spectacle lens.

almost useless to the aphakic patient. The visual field of this situation can be taken and plotted, as in Fig. 13. It can be confirmed rapidly on the perimeter as in Fig. 14 with the gross finger-wiggling method of visual field testing.

FIG. 13.—Visual field of right eye demonstrated in Fig. 12.

FIG. 14.—Ring scotoma of cataract spectacle lens, confirming the visual field defects shown in Figs. 12 and 13, by use of the perimeter.

For a well-centred round aphakic spectacle lens, the centre of the refracted field of view can be considered as the optical axis of the spectacle lens. In Fig. 15, note that the blind area has moved centrally almost 20° in the *field of view* as the eye is

FIG. 15.—Movement of blind area in field of vision as eye rotates.

rotated laterally. For the eye in primary fixation the blind area begins at 51° from the optical axis of the spectacle lens. For the eye fixing 30° laterally to the anterior optical axis of the spectacle lens, the blind area lies 32° laterally to the anterior optical axis. This 32° field of view for the eye rotated up, down, in, and out can be plotted as in Fig. 16. Note in Fig. 15 that, in wide lateral excursions of the eye, the pupil moves several millimetres away from the posterior optical axis of the spectacle lens. This moving of the pupil laterally causes the blind area to shift centrally. It is simply a phenomenon of unocular against-motion-parallax, with the obstructing object (the edge of the high-plus spectacle lens) being a short distance in front of the eye. This movement of the blind area towards the centre causes the "Jack-in-the-Box" effect shown in Fig. 17.

FIG. 16.—Visual field and field of view corresponding to Fig. 15.

FIG. 17.—"Roving" Ring Scotoma with its "Jack-in-the-Box" phenomenon.

Because visual field examinations will show the blind area to move towards the centre in the visual field towards fixation as the eye is rotated towards the periphery away from the optical axis of the high-plus spectacle lens, we have called this optically-blind area the "Roving" Ring Scotoma. Because of the "Jack-in-the-Box" effect, the blind area moves towards the centre in the visual field towards fixation at a greater speed than fixation is moving towards the blind area. This brings into use the complete term: the "Roving" Ring Scotoma with its "Jack-in-the-Box" phenomenon (Welsh, 1961). The blind area is not a true scotoma of the eye. It is an optically-produced defect at the edge of the refracted visual field and the refracted field of view. The blind area is created by the very strong prismatic effect at the periphery of a strong-plus spectacle lens.

Fig. 18 reminds us that a person with normal eyes orients himself to the side of his body both with peripheral vision and central vision aided mainly by ocular rotations, but also by head-turning and slightly by trunk-turning. This seeing to the side (and down or up) with wide ocular excursions is what aphakic patients call "side vision". They complain "there is no side vision" through aphakic spectacles, spheric or aspheric. "Side vision" might better be called "panoramic vision".

FIG. 18.—Ocular rotation panoramic vision with wide excursions of central vision and the visual fields.

Reviewing Figs 12 and 13, it can be seen that for spectacle-corrected aphakics the refracted field of view is markedly constricted for the rotating or so-called "roving" eye. To make matters worse, this totally blind area surrounds the refracted field of view. The extremely blurred unrefracted field and this blind area greatly limit the aphakic patient's "panoramic vision". For the spectacle-corrected aphakic, very rapid head-turning is the only answer to the partial restoration of "panoramic vision" which improves spatial orientation laterally, up, or down.

Contact lenses, as in Fig. 19, remove completely these most serious defects of spectacle-corrected aphakic vision. Contact lenses also eliminate the other defects of vision through aphakic spectacle lenses which will not be considered here. Rays can be considered as being bent only at the front surface of the contact lens. A correctly-fitted contact lens rests in contact with the cornea and rotates with the eye, thus allowing the return of an almost normal *refracted visual field* and a normal *refracted field of view* for the aphakic patient's "panoramic vision".

FIG. 19.—Clear focus achieved for wide angle of vision by use of corneal lens.

REFERENCE

WELSH, R. C. (1961). *Amer. J. Ophthalm.*, **51**, 1277.