**THE USE OF SPECTACLE LENSES FOR THE CORRECTION OF
REFRACTIVE AND OTHER ERRORS OF THE EYES
AND THE INSTRUMENTS USED FOR DE-
TERMINING SUCH ERRORS.¹**

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The use of lenses for the correction of ocular errors and for the improvement of vision goes back to prehistoric time. During the excavations of the ruins of ancient Nineveh a rock crystal lens was found, and in those early days the principles of reflection and refraction of light must have been well known. In our own England it is a matter of record that Roger Bacon, when he occupied the chair of philosophy at Oxford, obtained some fine glass from Belgium and from this, with his own hands, made some spectacles by grinding and polishing the lenses, which were afterwards given to an elderly friend and worn by him previous to 1286. Charles V, after his death in 1558, left among his valuables twenty-seven pairs of spectacles. But it is only within the memory of the present generation that the refinement of ocular corrections have been possible, owing to more perfect knowledge of the conditions within the eye, more refined methods of examination and greater skill in lens making.

All combinations of convex, concave, cylindrical, and prismatic lenses are used for the correction of ocular errors, and some ingenious devices have been used for properly adjusting and holding properly before the eyes the various combinations of lenses, from the clumsy split bifocal of Benjamin Franklin to the elegant invisible bifocal of to-day. The unit of strength of spectacle lenses is the lens which will focus parallel rays of light at one meter, or forty inches. This unit is called the Dioptric. A half Dioptric lens has half the strength and focuses light at two meters or eighty inches; one that focuses at half a meter is a two Dioptric lens, etc. Prisms are numbered according to their ability to deflect light, 1° , 2° , etc.

In speaking of the eye as an optical instrument I wish to emphasize one feature, *viz.*, that, except for the tunics or limiting membranes, the eye is an elastic and fluid body, each surface of transparent tissue being a refracting surface. In front of the eye we have the cornea, a tough, resistant, almost perfectly trans-

¹An address delivered before the Eastern Association of Physics Teachers at the Astronomical Laboratory of Harvard University, Cambridge, Mass., Dec. 2, 1911.

parent tissue, the front and back surfaces parallel and offering a strong convex refracting surface to entering rays. Posteriorly it is in contact with the aqueous humor—a fluid of the appearance and consistency of water, hence its name, the aqueous. Limited by the cornea in front and the crystalline lens behind, it is in effect a strong concavo-convex lens and a powerful refracting medium. Behind this is the lens of the eye, enclosed in its elastic capsule, a semifluid, transparent, sticky substance, having the outlines of a double convex lens. It is supported at its edges by a ring of muscular tissue, called the ciliary ring or the muscle of accommodation. This ring, by its contraction, diminishes the circumference of the lens and allows it, by its own elasticity, to become more convex and therefore more highly refractive. Inasmuch as this increase of convexity and increased focusing power necessitate muscular contraction of the ciliary ring, which must be constantly exercised and under constant variation during accommodation, it is not difficult to understand why the accommodation becomes weary and exhausted after long-continued use of the eyes, and particularly so in far-sighted eyes, which require constant focusing in order to bring the image on the retina at all. The lens is the only part of the eye that can be made to change its curvature at will and the only accommodative part of the eye. Behind this is the vitreous, a gelatinous, somewhat organized mass which fills the ball back of the lens. Thus we have a series of lenticular bodies, in contact with each other, each of different refracting power, not unlike the series of lenses found in high-class telescopes or microscopes. They are held firmly in contact with each other and under considerable internal tension.

A perfectly refracting eye is one in which parallel rays of light, on passing through the eye, are brought to a focus upon the retina without material accommodative effort, with the lens in its flattest condition, and with the muscle of accommodation relaxed.

A far-sighted eye is one in which the refracting media do not bring the rays of light to a focus far enough forward to form a perfect image upon the retina, and the accommodation must be exerted in order to give clear vision. This accommodative effort in such an eye is constant and eventually brings on the usual signs of exhaustion, spasm of the accommodation, headache, blur, inability to use the eyes, etc. This is corrected by a convex lens.

There is one other interesting point to make here. There is a certain relation between the effort of accommodation and convergence of the eyes. The greater the effort to focus the eyes the

greater is the effort at convergence. This action is automatic and proceeds from and is controlled by nerve centers in the brain. If these relations are harmonious and well balanced, vision and accommodation proceed without undue strain, but if either is out of harmony with the other most disastrous nervous disturbances result. This is a fertile and interesting field of study and practice for the neurologist and ophthalmologist.

As one grows older the tissues become firmer and less elastic. This is true of the eye and results in hardening of the fluid lens, making it less elastic and more resistant to changes of curvature and at the same time the ciliary muscle is less able to influence the curvature of the lens. As the result of these two changes the accommodation for near vision becomes impaired and only by holding the object at a more remote distance can small objects be seen clearly and soon even that power is lost. A convex glass converges the rays of light and brings the focus to the retina—the thing which the unaided eye can no longer do. This failure generally begins at about forty-two years of age and becomes well marked at forty-five.

Near-sightedness is the condition in which the focus is in front of the retina. There is no relief by an accommodative effort because such effort would bring the image still further forward and aggravate the condition. As the result of nonuse of the ciliary muscle it becomes weak and atrophied and the retina enfeebled. Such conditions tend to become more aggravated with time and neglect, and often almost total destruction of vision ensues. A concave glass corrects this condition.

The first recorded case of astigmatism dates from the year 1801. This term simply means that the curvature of the eye in one meridian is not the same as in other meridians, and while lines in one direction are well focused those in another direction are not so clearly focused, or, to state it in another way, the curve of the cornea is not a perfect spherical segment but somewhat flattened from opposite sides, or to speak more mathematically and exactly, its surface will not present that of a perfect surface of revolution, but that of a triaxial ellipsoid. This condition is most prolific of reflex disorders of all kinds and of severe character. Headaches, neuralgias, congestions, indigestion, confusion of mind, and a long train of symptoms are associated with this error. It is easy to see how difficult and well-nigh impossible it must be for the ciliary muscle to in any way correct this irregular and ill-balanced distortion of the cornea, and how exhausting such at-

tempt must be. This error is largely located in the cornea—though not always nor entirely so. It may be caused by faulty development of the cornea or lens, by the unequal pressure of the lids upon the cornea, by the undue tension of the muscles which move the eye in its socket, or by irregularities in the bony walls of the orbit. It may be corrected by cylindrical lenses.

The muscles which move the eyeball are mostly arranged in antagonistic pairs and on opposite sides of the ball, the contraction of one muscle and the relaxation of its opposite moving the eye in the corresponding direction. If these are not well balanced or improperly attached to the eyeball this fault gives rise to a characteristic train of symptoms, like dizziness, nausea, pain in the back of the head, congestion at the base of the brain, etc. This error is corrected by prismatic lenses.

While each of these conditions, taken separately, seems to be amenable to correction, yet such is not always the case. They seldom come singly but usually several of them are combined in the same eye and often different complications in the separate eyes, so that the proper correction and balance of forces is far from easy and calls for considerable judgment and experience. The disturbance of nerve functions and perversion of sensibility associated with these errors often demand considerable insight into both the physiology and psychology of our patient.

Fortunately we have many instruments of precision to aid us in diagnosis. The use of the test lens and test cards are familiar to all. Of the test lens I have already spoken. The test card deserves some mention. It is the result of much study and experiment. The basis of the system is as follows: The average retina can distinguish distinctly a space which subtends an angle, at the retina, of one minute. If we take five such spaces in each direction and outline our standard test-letter within that square and with each line of the letter one space wide we shall have a figure each part of which will form an image upon the retina which will subtend an angle of one minute, which is as small as the majority of eyes can see. The distance for which such a standard letter is constructed is twenty feet, that being the distance at which lines of light are practically parallel, so far as the eye is concerned. For a greater distance a larger letter must be made and for a shorter distance a smaller letter. Hence the series upon test cards. If the twenty foot letter is seen at twenty feet the vision is said to be 20/20, the numerator being the distance at which the letter is seen and the denominator indicating the size

of letter that is distinguished. If the forty-foot letter is the smallest that can be seen at twenty feet the vision is said to be 20/40, and so on. The opinion of the patient as to how well he can see and which lens gives the best vision is of value in proportion to the patient's perceptive powers, his habits of observation and comparison, his general intelligence and efforts at co-operation. But the results vary so much and are liable to so many errors, both of observation and judgment, that the examiner always distrusts his results obtained in this way and welcomes any device that eliminates the personal element from his work.

Perhaps the simplest and most reliable of these is the retinoscope and the method of determining the refraction with this instrument is called retinoscopy or studying the reflection of light as thrown back from the retina of the patient. If a pencil of light is thrown into a perfectly refracting eye the light will be focused upon the retina and reflected back through the pupil, after passing through the various refracting media twice, in the same direction and in the same parallel condition as it entered the eye. If the eye of the observer be placed in the course of such reflected light he will be able to see the reflected image and study any slight movement he may impart to the entering rays as the light is reflected. The principle involved is that if the refracting media of the eye are so perfect as to converge the parallel entering rays and bring them to a focus upon the retina, the same rays reflected from the retina and passing through the same media in reverse order, will emerge from the eye parallel, as they entered. But if the refracting media of the eye do not focus the light perfectly, then the emerging rays will not be parallel and will not respond to the experimental movements of the rays and the variations will be interpreted by the examiner to indicate certain errors. When a lens has been placed in position in front of the eye, of such strength as to correct the observed errors, the reflected light will become parallel and so inform the observer. It is evident that this added lens will be the correction for the refractive errors of the eye. By this method the examiner can rely upon the infallible laws of light for his diagnosis instead of the fallible and uncertain observation and opinion of himself and his patient.

Another valuable aid is the ophthalmoscope, which enables the physician to see the retina, directly and clearly, and at the same time note the strength of lens needed in order to get the most perfect focus upon the retina. This lens is the measure of the error

of the eyes of both the observer and the observed. By subtracting the known error of the examiner the remainder is approximately the correction sought. Not only does this instrument help in determining the refraction, but enables the physician to actually see and examine in detail every part of the internal eye, the retina, the choroid, the vitreous, the lens, the iris, the aqueous, the cornea, and the optic nerve. The principle is simply to reflect light into the eye and, through a hole in the reflecting mirror, to look into the illuminated eye.

The ophthalmometer is an instrument used to measure the curvature of the cornea, and as most of the astigmatism lies in that tissue this instrument becomes of value in that condition. The instrument is complicated but the essential principle is simple. Two illuminated objects are placed before the eye and the light from each falls upon the surface of the cornea and is reflected forward to the observer, and the distance between the images is carefully measured. In point of fact, the objects are brought near enough to each other for the images to be in contact. Then the objects are revolved into a position at right angles to their former position and their distance apart is noted. If the cornea presents a perfect curve the distance between the images will remain as before. The difference in their distance in the different positions gives the data for computation of the curve of the cornea in its different meridians, and by repeating the observations it is not difficult to determine the meridian of greatest curvature and the meridian of least curvature. This will give the axis of the astigmatism and its amount. If the astigmatism were all in the cornea this would be absolute, but unfortunately for the usefulness of the instrument, the other media, especially the lens, may be the seat of astigmatism also, so that the ophthalmometer is of limited use only.

In describing these instruments I have eliminated many elements and modifications and have made statements which may not be absolutely accurate in order to simplify the descriptions and to emphasize the salient elements and principles of each. They all help in diagnosis but, after all, the use of common sense and experienced observation count for much in adapting theoretical findings to the alleviation of suffering. We must always recognize that we not only a delicate optical instrument with which to deal, but also a most sensitive living tissue.