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THE HARMONIOUS NON-SYMMETRICAL ACTION OF THE OBLIQUE MUSCLES EXPLAINS "BINOCULAR ASTIGMATISM."

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At the meeting of the section of ophthalmology, American Medical Association, in Cincinnati last May, Dr. Culbertson read his paper on "Binocular Astigmatism," which has since been published in the AMERICAN JOURNAL OF OPHTHALMOLOGY, vol. V., No. 5, p. 117. During that meeting I discussed his paper, supposing that what I was saying was being noted by our shorthand reporter for publication in the Journal of the Association, in connection with Dr. C.'s paper. The reporter failed to get any of the discussions of that meeting in a shape worthy of preservation, so that all was lost save to those who heard. I am not sorry on account of the loss of my discussion of Dr. C.'s paper, for the limited time, though kindly extended, was not sufficient for a clear exposition of what he had termed "Binocular Astigmatism."

The phenomena suggesting to him the subject on which he wrote were: imperfect vision, proximal and remote; distortion of a rectangle (3x12 inches) at a distance of one metre or less; and inclination of a level surface, as the floor, all of these being caused by the use, in binocular vision, of cylindrical lenses that had been carefully adjusted in monocular examinations. That these phenomena do occur in some cases of astigmatism has been observed by every ophthalmic surgeon of any experience; but I presume that Dr. C. is almost alone in the practice of changing the axis of the cylindrical glass for one eye (sometimes for both) in order that these phenomena may be made to disappear. That such practice was ever entirely satisfactory is but evidence of the self-adjusting power possessed by eyes, as well as their power of endurance. That lenses so changed would be better than no glasses at all, I can understand. That he ever found the changing of one axis better than the changing of both is strange, for reasons that will be given further on in this paper. That in one case he would have to change the axis of the right glass and in another the axis of the left is susceptible of explanation which will be given further on. That the changing of either axis is bad practice I will be able to prove.

For the phenomena referred to above, observed by many for years, no attempt at an explanation had been published, so far as I know, previous to Dr. Culbertson's paper; yet the true cause of all these phenomena, viz., *the rotation of the eyeballs by the harmonious non-symmetrical action of the oblique muscles* was discovered by myself more than three years ago, which discovery I set forth in a paper read in the Ophthalmic Section of the American Medical Association, at its meeting in Chicago in June, 1887, and published in the Journal of the Association, Nov. 5, 1887. Although that paper occupied more than the allotted time, I regret that I did not refer to these phenomena specifically, as it would have demonstrated better than anything else the correctness of the theory of rotation advocated in it.

There can be but three explanations for these phenomena,

and of these three there can be but one correct. The first (because I shall examine it first) is Dr. Culbertson's theory of rotation of the eyeballs by the recti muscles; the second, Martin's theory of sectional contraction of the ciliary muscles; and the third, my own theory of rotation of the eye-balls by the harmonious non-symmetrical action of the oblique muscles.

1. Dr. Culbertson's theory—what is it? Let me quote from his paper (p. 118): "But it is evident that in proximal vision the interni, the inferior oblique, and the superior and inferior recti muscles must exercise increased force and act in concert." In criticism of this statement I would say that the acting extrinsic muscles of the eyes in near vision are the interni, the inferior recti and the superior oblique, the interni causing the visual axes to converge, the inferior recti causing those axes to point downward toward the page, and the superior oblique preventing the loss of parallelism between the vertical meridians of the corneæ, which would occur if the inferior recti were unopposed in their action. In proximal vision only these muscles act, except in certain cases of astigmatism when, for the betterment of vision, the superior oblique of one eye is made to act too powerfully, rendering it necessary for the inferior oblique of the opposite eye to act correspondingly, in order to prevent double vision. *The naturally vertical meridians must be kept parallel if not vertical, else double vision would result.*

Again (p. 119): "Let the following case illustrate. In binocular proximal vision, suppose that the left inferior oblique fails to act sufficiently to maintain the axis of rotation vertical, and that the inner fibres of left superior rectus inclines said axis at its upper extremity toward the nose; then the rays of light will no longer cut the cornea in its vertical meridian, but toward the temporal side of the should-be vertical plane of the cornea. If the defective axis of the cylinder was at an angle of 180° in remote vision, for proximal vision the axis of the glass will have to be turned upward toward the displaced axis of rotation of the eye-ball, as many degrees as this axis has deviated from the normal vertical perpendicular. If

it be 10° then the angle would be 10° instead of 180° for the cylinder, the scale running from the temporal side. In other words the measure of deviation of the axis of rotation is the number of degree of axis-displacement of the cylinder required in order to cause both sides of our object board to appear parallel."

In criticism let me say: If the language just quoted is correct, the patient, in reading, must have held his book above his head, since contraction of the superior rectus would cause the axis of vision to point upward; or if looking at the rectangle that, too, must have been held above his head. Granting that the doctor intended to say inferior rectus instead of superior, and superior oblique instead of inferior, what would have happened? In either case *parallelism* between the naturally vertical meridians would have been lost, and *double* vision would have resulted, one image, if board was used, being a perfect rectangle as seen by right eye, while the other image would have been a four-sided figure, leaning and narrowed at one end. Moving the axis of his cylinder would have widened the end, but the image would still lean, and vision would still be double. Possibly the confusion of double images would have been so great that the deformity of one image would not have been noticed.

What the doctor names "binocular astigmatism" cannot be caused by what he would term "unbalanced action" of a rectus and oblique muscle of one eye, the action of these muscles in the other eye being perfectly balanced. Can it be caused by the "unbalanced action" of the inferior recti and superior oblique, or, if the card-board is held above the head, the superior recti and inferior oblique of both eyes? If the inferior rectus of right eye is not sufficiently opposed by its superior oblique, the former will so rotate the eye as to make the upper end of the vertical meridian of its cornea (the meridians of the cornea end at corneal margin, therefore I may say "end of meridian") point up and out; if the inferior rectus of the left eye is not sufficiently opposed by its superior oblique, then the former will cause its eye to so rotate as to make the upper end

of its vertical corneal meridian point up and out. This would make the naturally vertical meridians of the corneæ divergent at upper corneal margin and convergent below. Marked double vision would result, the two images of a vertical object, leaning toward each other at their tops. If we could suppose that double vision would not result, the image of the object looked at through the glasses as adjusted in the monocular examinations, if a rectangle, would be narrow at the top and wide at the bottom, a phenomenon not referred to by Dr. Culbertson.

It is clear that the explanation for "binocular astigmatism," as given by Dr. Culbertson, is not correct.

2. Toward the close of his paper (p. 123) Dr. C. says his explanation may not be true, and adds: "Accommodation may have a direct influence in the result, by changing the focus of individual sectors of the crystalline lens," referring to Martin's theory of the sectional contraction of the ciliary muscle.

The fact that "binocular astigmatism" exists to some extent in some cases when all ciliary power has been suspended by atropia or homatropia, is strong proof that sectional ciliary action does not cause it. I am not convinced that sectional ciliary action ever occurs, but I am sure that it never causes "binocular astigmatism."

Let us study, in reference to Martin's theory, a case of simple hypermetropic astignatism, with the emmetropic meridian in right eye at 75°, and that of left eye at 105°. Under suspension of accommodation we find the glasses needed to be +3 cyl. ax., for right eye at 75°, and for left at 105°. If Martin's theory be true, such eyes, when uninfluenced by medicine, have the power of partly correcting their faulty, without changing the refraction of their correct, meridians. To do this that part of the ciliary muscle behind the meridian at 75° in right eye, must not act while every other part must be thrown into action, the maximum of power being exerted by that part behind the meridian at 165°. The same may be said of the left eye substituting 105° for 75° and 15° for

165°. Does this kind of action occur in such eyes? I have never seen the evidence. If it were to occur while the correcting lenses are being worn, distant vision would be more blurred than near vision, but rectangles would have their natural appearance and the floor would not slant. The only thing to be done in such a case would be to give a weaker pair of cylinders (a practice based on Martin's theory) allowing the axes to remain as before.

Again taking the same pair of eyes we may suppose that the ciliary strain at the points corresponding to 90° is just enough to make those meridians emmetropic without affecting the originally emmetropic meridians. Then rotate the cylinders, the one for the right eye from 75° to 90°, and the one for the left eye from 105° to 90° so that they may correspond with the (supposed) newly made emmetropic meridians; and you will find that the part of the cylinder corresponding to 75° in one eye and 105° in the other, has a converging power of .50 dioptres, necessarily focusing in front of the retinæ the rays passing through those meridians. Such a condition would distort and dim objects near and far, whether the positions of the axes of the cylinders remain at 90° or be placed back at 75° and 105°.

Or again we can suppose that the ciliary strain, while making the vertical meridians emmetropic, so acts on the formerly (naturally) emmetropic meridians as to make them myopic—it could not make them hypermetropic. The lenses placed as before would only distort and dim objects still more, which no moving of cylinders could improve.

To me it is clear that ciliary strain, sectional or general, does not cause the phenomena giving rise to the name "binocular astigmatism." That ciliary strain can aggravate the acting cause of "binocular astigmatism" is true.

3. The cause of "binocular astigmatism" is the *harmonious non-symmetrical action of the oblique muscles*, which function was discovered by myself and explained in the paper read in Chicago, already referred to. By the expression "harmonious non-symmetrical action of the oblique muscles" I mean that

the superior oblique of one eye acts with the inferior oblique of the other in such a way as to rotate the eye-bails so as to alway keep the naturally vertical meridians parallel, thus preventing double vision. For instance, the right *superior* oblique by contracting may roll its eye-ball so that the naturally vertical meridian, instead of being allowed to stand at 90°, is made to stand at 75°, and at the same moment the left *inferior* oblique will roll its eye so that its naturally vertical meridian is made to stand at 75°, the two being still parallel though leaning. This peculiar function is exercised in most if not in all cases of astigmatism, before correction by means of lenses, when the best meridian of one or both eyes is somewhere between the vertical and horizontal meridians; and the object of the action is to make the emmetropic meridian approach the vertical, if nearest it, or the horizontal, if nearest it, so as to make vision sharper.

Take a case of simple hypermetropic astigmatism with the best meridian in each eye at 105°, no glass ever having been worn. To sharpen vision the superior oblique of the right and the inferior oblique of the left will revolve their respective eyes so that the emmetropic meridian of each eye will be brought to the vertical, having described an arc of 15°. While doing near work these muscles will hold the emmetropic meridians in their new positions until forced by fatigue to resume a state of rest. This habit of rotation is formed early, and continues throughout the life of the individual, unless a pair of correcting lenses are given. At first, even with the glasses on, the old habit of rotation may continue, and if so, some of the phenomena of "binocular astigmatism" will appear. The rectangle will be but little changed, but the floor will slant from left to right, which phenomenon will continue until the eyes learn that vision is now sharper and easier without than with rotation, at which time the harmonious non-symmetrical action of the oblique muscles will cease.

Again take a case of simple hypermetropic astigmatism, the emmetropic meridian being at 75° in right eye and at 105° in left eye. The inferio r oblique of the right eye can place its

emmetropic meridian at 90°, but at the same moment the superior oblique of the left eye will move its emmetropic meridian from 105° to 120°, the vision being sharpened in the right eye by the rotation, but more blurred in the left eye. During this state of things the mind takes cognizance of the image in the right eye only. Let these muscles become fatigued, and, in a moment the work is shifted from them to the superior oblique of the right eye and the inferior oblique of the left eye, thus placing the best meridian of the right eye at 60° and that of the left at 90°, the sharper image, the one the mind considers, being this time in the left eye. This shifting of labor may occur once or many times during the long continuance of near work. Now a proper cylinder having been given each eye, the axis of one at 75° and that of the other at 105°, the old habit of rotation may continue for a time; if so there will appear some of the phenomena of "binocular astigmatism." With the glasses on, if the eyes are revolved by the inferior oblique of the right and superior oblique of the left eye, the right end of the rectangle will be narrowed, its left border will incline from left to right, and its lower border will slope up from left to right and the floor will slant from right to left. Let the labor be shifted to the superior oblique of the right eye and the inferior oblique of the left, than the left end of the rectangle will be narrowed, the right border will incline from right to left, the lower border will slope up from right to left, and the floor will incline from left to right. In both cases the upper border will be shortened.

Examples could be multiplied, if necessary, for the establishment of the fact that there is a harmonious non-symmetrical action of the oblique muscles which is exercised in many if not in all cases of astigmatism when the best meridians happen not to be vertical or horizontal; and that the rotation of the eye-balls resulting from this action, if continued from habit after the proper glasses have been given, causes the phenomena of "binocular astigmatism."

Every ophthalmic surgeon may produce in his own person

all the phenomena of "binocular astigmatism." His own eyes must be emmetropic naturally or by means of proper glasses; then let him by means of convex cylinders in the back division of his trial frames produce myopic astigmatism in his own eyes, and then with concave cylinders of same power in front division of trial frames, correct his artificial myopic astigmatism. So long as the axes of these cylinders coincide vision proximal (provided there is no presbyopia) and remote will be perfect, the rectangle will be a rectangle still, and the floor will not incline; disturb this relationship and you dim vision, distort the rectangle and incline the floor. To be specific: let the experimenter put a+3 cylinder for each eye in back part of his trial frames with axis of right at 20° and that of left at 160°. He thus produces simple myopic astigmatism in each eye, the emmetropic meridian in his right being at 20° and that of his left at 160°. It is clear that glasses ground after the following formulæ will fully correct this defect; for O. D.—3 cyl. ax. 20°.

" O. S.—3 " " 160°.

Disturb this relationship between the axes of these cylinders and the emmetropic meridians (axes of convex glasses) of the artificially myopic astigmatic eyes, as the relationship would be disturbed by the contraction of the superior oblique of one eye and the inferior oblique of the other, if the astigmatism was not artificial, then the rectangle loses its shape, and the floor slants. Suppose the convex cylinders (those producing the defect) inseparably connected with the eyes, moving with their every motion, hence, subject to the action of the oblique muscles, then the right superior oblique rolling its eye carries the axis of its cylinder from 20° to 180°, and the left inferior oblique likewise carries the axis of its cylinder from 160° to 140°, the axes of the correcting (concave) cylinders still remaining at 20° and 160°. This change would narrow the right end of the rectangle, and slope downward its upper border from left to right, and would make the floor appear to slant from left to right. Or if the inferior oblique of right and superior oblique of left act in like manner, then the

emmetropic meridian of right eye would be at 40° and that of left eye at 180°, the correcting (concave) glasses still having their axes at 20° and 160°. This would narrow the left end of the rectangle, make its upper border slope down from right to left and would cause the floor to slant from right to left.

Again we may produce with the same + 3 cylinders simple myopic astigmatism letting the emmetropic meridians be at 20° in each eye. The correcting glasses would be the — 3 cyl. ax. 20°. Still supposing that the + 3 cylinders are movable with the eye-balls, then the right superior oblique rolling its eye would carry the axis of its cylinder from 20° to 180°, and the left inferior oblique would, in like manner, change the axis of its cylinder from 20° to 180°, the axes of the correcting cylinders still remaining at 20°. This disturbed relationship would develop the following phenomena: rectangle not much altered but possibly a little narrower at left end and upper border on account of changed direction (slight) of right and lower borders; floor slants from left to right.

With the same + 3 cylinders, produce simple myopic astigmatism so that the perfect meridian of right eye shall be at 20° and that of left at 110°. The correcting lenses would be the — 3 cylinders with their axes at 20° and 110° respectively. Still supposing the + cylinders to move with every movement of the eyes, then the right superior oblique, in revolving its eye, would move the axis of its cylinder from 20° to 180°, and the left inferior oblique, in like manner, would move the axis of its cylinder from 110° to 90°, leaving the axes of the correcting lenses at 20° and 160° respectively. With this displacement, by revolution, of the perfect meridians, are developed the following phenomena: the right and left borders of the rectangle lean towards each other at the top thus shortening the upper border, lower border possibly a little curved, the convexity looking up, and the floor a little curved in same way.

These experiments can be multiplied indefinitely, each time

some of the many interesting phenomena of "binocular astigmatism" showing themselves.

Experiments as to simple hypermetropic astigmatism may be performed by making the — 3 cylinders take the place of the + 3 cylinders and vice versa, in the experiments just noted. I had intended giving the details of fourteen experiments, but my paper is growing too long.

It is interesting to notice that, in those experiments in which a disturbance of the true relationship of the axes of the correcting lenses and the axes of the astigmatic-producing lenses (the emmetropic meridians) brings about a narrowed condition of the right end of a rectangle and a slanting condition of the floor from left to right, by making the axes af the right lenses only coincide again, the floor is made almost level but the right end of rectangle remains narrowed; while, by making the axes of the left lenses only coincide, the floor is leveled and the ends of the rectangle appear equally wide. This corresponds with what Dr. Culberton observed on moving only one lens in his recorded cases (the first part of my observation above noted he did not record). If the left end of the rectangle is the narrowed one, and the floor slants from right to left, then the moving of the right cylinder in the proper direction corrects these appearances. But by moving the right cylinder only when the left end of the rectangle is narrowed, or the left cylinder only when the right end of rectangle is narrowed, in order to make both ends equally wide, we do not obtain a perfectly formed rectangle. If Dr. Culbertson had pressed his inquiries his patients would have said: "While the ends of the rectangle are now of equal width, the upper margin is shortened by the right and left margins leaning slightly towards each other at the top." To have corrected the rectangle perfectly he should have moved both cylinders in the same direction and through the same are, so as to make the axes of the correcting lenses and the rotated emmetropic meridians coincide.

If what I have taught in this paper is correct—that it is correct any ophthalmic surgeon may soon convince himself by

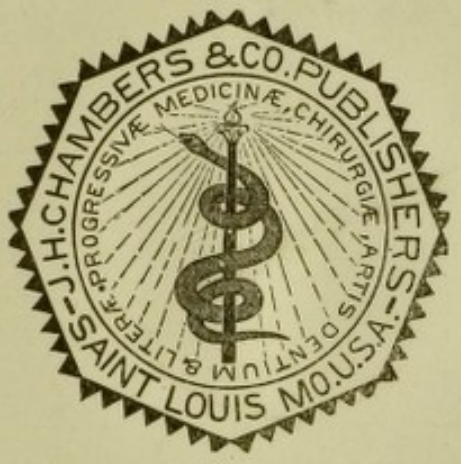
thought and experiment—Dr. Culbertson's practice of changing the axis of one cylinder for the correction of "binocular astigmatism" is erroneous, as would be the practice of changing the axes of both cylinders. Such glasses would be better than none, but the eyes would have to continue to rotate, however with better effect, for the rotation now gives perfect vision, whereas before the glasses were given there was only an approach to perfection of vision. For example, by monocular tests it is found that the natural location of the emmetropic meridian of the right eye is at 20° and that of the left is at 160°; and the correcting lenses are placed in the trial frames accordingly. In binocular vision, if the old habit of rotation is kept up, the left superior oblique may at once roll its eye so that its best meridian stands at 180°; and at the same moment the right inferior oblique, acting in harmony with the left superior oblique, must roll its eye so that its best meridian is moved from 20° to 40°. In this state of things the left end of the rectangle is narrowed and the floor slants from right to left. On turning the right correcting cylinder from 20° to 40° so that it may coincide with the emmetropic meridian in its new position, the floor is made level and the two ends of the rectangle appear of equal width (as said before the upper margin of rectangle is shortened,) effects, as to rectangle, that cannot be gained by changing the position of left cylinder only, from 160° to 180°, so that it might coincide with the best meridian of the left eye in its new position. Then with the axis of left cylinder at 160°, as determined in the monocular test, and with axis of right cylinder changed from 20° (point determined in the monocular test) to 40° (point to which the emmetropic meridian has been rotated), while the superior oblique of the left and the inferior oblique of the right eye continue their harmonious non-symmetrical action, there is absolutely perfect vision in the right eye but blurred vision in the left. Let this pair of muscles become fatigued, then they relax their straining power and the eyes roll back into the position of rest (naturally vertical meridians vertical), so that the emmetropic meridian of the left eye comes again to its natural

position (160°,) exactly coinciding with the axis of its correcting cylinder; and the emmetropic meridian of the right moves from 40°, the point to which the axis of its cylinder had been changed, back to 20°, its natural position. During the continuance of this rest there is perfect vision, proximal and remote in the left eye, but blurred vision in the right. But in this state of rest of the oblique muscles, the floor is made to slant from left to right and the right end of the rectangle is narrowed, due to the changed position of axis of right cylinder, so that vision is not so comfortable; and in a short time the originally acting muscles resume their work. This process must be repeated so long as such glasses are woru. Without the glasses the rotation must be through a greater arc, but the one pr. of obliques "spells" the other; with the glasses all the rotation is accomplished with one pair but the arc of rotation is greatly lessened, therefore these glasses may be more comfortable than none.

In the example just given, if the axes of both cylinders had been changed so that the axis of the left would have been at 180° while that of the right cylinder stood at 40°, the points to which the emmetropic meridians had rotated, there would then have been perfect vision in both eyes, the floor being level and the rectangle perfect (not narrowed at the top as it was when only the axis of the right cylinder was changed). With the two axes thus changed the price of perfect sight is tonic contraction of the superior oblique of the left eye and the inferior oblique of the right; but the degree of contraction being less—a smaller arc to be described then when, without glasses, one pair of obliques would shift the labor to the other—than that to which they had been accustomed, they may bear this strain with some degree of comfort.

The correct practice in all cases of astigmatism is to give the fully correcting lens, and to place its axis so that it will coincide with the best meridian in its natural position, which can always be found in careful monocular examinations with accommodation suspended. There will be no tendency to rotate, the habit of rotation never having been formd, if the axes

of the cylinders are needed at 90° or 180°. In some cases, the emmetropic meridians not being vertical or horizontal, the habit of rotation is broken at once on commencing the use of glasses, and no "binocular astigmatism" is noticed; but in other cases the habit of rotation continues from a few hours to a few days, "binocular astigmatism" necessarily resulting. The disposition to rotate is aggravated by accommodation, hence in rebellious cases either direct the patient to voluntarily abstain from "near work," or else suspend his accommodation with atropia for a few days. In all cases the phenomena of "binocular astigmatism" will pass away in a longer or shorter time, if the axes of the cylinders have been properly placed; for the eyes will learn that there is now no longer any need for rotation—that rotation now makes vision worse and not better. To determine the position of the axis of the cylinder is the most difficult part of tne work of refraction, and always requires patience and time. I devote from two to three consecutive hours to every case of astigmatism, and examine each eye separately, and in all persons under 50 years of age I fully suspend the accommodation by means of homatropia.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