SOME CLINICAL ASPECTS OF LENTICULAR
ASTIGMATISM.*

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The subject of astigmatism has for its keynote the astigmatism of the lens. This is not only of interest from a scientific standpoint, but it is also of vital importance in the management of cases. It is not sufficient that we know the total astigmatism of an eye, unless we wish to prescribe glasses largely from the anatomic standpoint. In order to obtain a correct idea of the conditions present in each given case, we must separate the comparatively fixed quantity, the corneal astigmatism, from the fluctuating and uncertain one, the astigmatism of the lens. Leaving aside the differences in the corneal surfaces and the eccentricity of the visual axis, both of which quantities are so small as to be negligible from the clinical standpoint, the two broad facts to be determined are the amount of corneal astigmatism and the amount of lens astigmatism.

The corneal astigmatism, which is congenital in the vast majority of cases, may be determined accurately by the ophthalmometer of Javal and Schiotz. It may be stated in the beginning, however, that we have at present no accurate means of measuring the lens astigmatism, either as regards its quantity or its axis, but must depend on the subtraction of the corneal from the total astigmatism, as obtained by one of several methods.

VARIETIES OF LENS ASTIGMATISM.

Lens astigmatism may be either static or dynamic, and is probably far oftener the latter than the former. It would otherwise be difficult to explain the occurrence of so many cases of corneal astigmatism of low degree (0.5 diopter) accurately compensated by the lens, especially in hyperopic cases with a well-developed ciliary muscle, and it hardly seems logical to attribute the cause of this to static astigmatism when we consider how small the measured change must be. In support of this, we have the clinical fact that low degrees of corneal astigmatism in myopic cases are much less frequently compensated by the lens; that is, they frequently accept cylindric glasses entirely at variance with the ophthalmometric reading, and this we should expect, because the ciliary muscle is relatively weaker, and because accommodation has no effect in increasing the visual acuity in use of the eyes for distance vision.

We are more apt to find this variation in the lens astigmatism the higher the total myopia and the weaker the ciliary muscle. That there exists a primary static astigmatism of the lens can scarcely be doubted, but that it exists unchanged in many instances may be very much doubted. Donders¹ found in his own eye astigmatism produced by the tilting of the lens, and that this can occur must be acknowledged by those who have seen astigmatism produced by a partial luxation of the crystalline lens. Children frequently learn to overcome low degrees of astigmatism by tilting the head, and presumably tilting the lens in relaxation of the zonula during accommodation. It is also a matter of common experience to see a patient with spherical glasses overcome an astigmatism by looking obliquely through the lens. Aside from these exceptional cases, however, which usually have rather pronounced clinical

features, dynamic lens astigmatism is, in all probability, most frequently caused by partial contraction of the ciliary muscle in the meridian of least refraction, allowing that meridian of the lens to become, within certain degrees, more convex.

If the tilting of the lens were a frequent cause of dynamic astigmatism, we should expect it to appear fully as frequently in presbyopes as in the young. Exactly the reverse is true. Astigmatism in presbyopia becomes manifest just as certain other errors do, unless, of course, we have a static astigmatism of the lens, and it is doubtful if dynamic astigmatism occurs at all after the age of 50.

Lens tilting argues an even higher individual development of control over the ciliary muscles, inasmuch as the mechanism by which it is produced must be the drawing forward of a certain set of ciliary fibers confined to a very small area. It is doubtful if this highly specialized action of the muscle exists frequently. Indeed, all the cases of lens tilting that have come under my observation have been, I believe, due primarily to the action of gravity in the twisted positions of the head which such patients assume.

Aside from the cases of lens tilting due to partial luxation of the lens, I have never seen a case where lens tilting seemed to occur during the distance test, these cases occurring only during accommodation at the near point.

Compensation by lens tilting must be extremely small, and is undoubtedly less in amount than compensation by partial contraction.

Partial contraction of the ciliary muscle was first pointed out by Dobrowolsky.² This view has been accepted by Landolt, Woinow, Pflüger, Mauthner, and others, while it has been opposed by no less distinguished observers than Hess, J. G. Bull, Sulzer, and Tscherning. The question is by no means settled, but it certainly seems as if the advocates of a dynamic lenticular astigmatism had a great deal in their favor, for the clinical facts and the voluntary control of the eye over astigmatism seems difficult to explain by any such fortuitous occurrence as dropping of the lens, tilting of the lens on the axis, or any of the other changes in the lens causing astigmatism, which, while they undoubtedly occur and have been demonstrated, certainly can not be the cause in the majority of cases.

The experiments of Hensen and Voelckers³ are in the highest degree convincing, as showing that a meridional contraction of the ciliary muscle is possible, whatever may be its action on the shape of the crystalline lens. They found that irritation of the ciliary nerves by an electric current was followed by contraction in only that part of the iris and ciliary muscle supplied by that nerve. They also introduced needles through the sclerotic and cornea, and observed by the tilting forward of the needles which ones were acted on when a certain ciliary nerve was stimulated, proving that the choroid is drawn forward in accommodation. They observed in the same manner changes in the curvature of the lens, by placing the ends of the needles in contact with the anterior and posterior surfaces of the lens. This was demonstrated in living animals—dogs, cats and monkeys—and also on a freshly enucleated human eye. The point of application of the electric current in the animals was near the ophthalmic ganglion.

* Read in the Section on Ophthalmology of the American Medical Association, at the Fifty-ninth Annual Session, held at Chicago, June, 1908.

1. Accommodation and Refraction, p. 532.

2. Arch. f. Ophth., 1868, xiv, 3, 51.

3. Exper. Untersuchung über den Mechanismus der Accommodation, Kiel, 1868; also Arch. f. Ophth., 1873, xix, 1.

CLINICAL DIFFERENTIATION.

From a clinical standpoint, we must distinguish carefully the static and the dynamic astigmatism of the lens. I think all will agree that the latter exists, no matter how it may be produced. It seems impossible otherwise to explain the vast number of persons whose corneal astigmatism is reduced 0.50 or 0.75 diopter, so that, having that amount of corneal astigmatism, no amount of refractive error can be demonstrated either with or without a mydriatic.

As Landolt⁴ points out, "It may easily be demonstrated that the eye succeeds with a certain effort in overcoming weak cylindrical glasses. By what mechanism would it be possible to neutralize the inequality of refraction produced by the cylinder if not by the unequal contraction of this ciliary muscle, followed by a corresponding change in the form of the crystalline? This unusual and, for the non-astigmatic eye, unnatural muscular action reveals itself, moreover, by a rather disagreeable sensation, which from its resemblance to the one experienced during fixation of the punctum proximum leaves no doubt as to its origin. . . . The contraction of this muscle, limited to a single meridian, must cause unequal relaxation of the crystalline and make it assume a more convex form in one meridian only." It may easily be demonstrated, by putting a -0.50 cylinder before the eye (which is the utmost that I personally can overcome), that variations in the position of the head have no effect on the ease with which this cylinder can be overcome in the majority of cases, but only in the exceptional cases of "lens tilting" mentioned.

The dynamic astigmatism of the lens could hardly be expected to exceed a fraction of a diopter, and in practice this is found to be the case. The earlier text-books on refraction frequently led one to believe that a very considerable amount of astigmatism might be uncovered by the use of atropin, but, as a matter of fact, we do not find this to be invariably the case, and even in those whose accommodation is young and vigorous any more than 0.50 diopter blurs distant vision. In practice, I find myself more and more inclined not to give cylindrical glasses, unless they improve the vision, and even if I have occasion to use a mydriatic and develop what may be called a latent astigmatism I do not by any manner of means feel sure that such a glass can be worn after the effect of the mydriatic has passed off. However, the occurrence of these cases of latent astigmatism is a very strong point in favor of partial contraction of the ciliary muscle.

A dynamic astigmatism of the lens, which persists for a certain length of time, may lead to one of two secondary changes in the eye. The first of these is a greater development of the fibers of the ciliary muscle in the meridian of contraction. There seems no reason to doubt this in the face of the accumulated proof of the muscular development of the whole ciliary body in hyperopic cases (Iwanoff). The second change is in the shape of the lens. A lens in which a dynamic astigmatism persists for a certain length of time gradually becomes fixed in that shape, as the nuclear sclerosis advances. This is shown by those cases of corneal astigmatism of two or more diopters in which there is normal vision with only a fractional cylinder. Even with the aid of a mydriatic it is impossible to develop a greater lens astigmatism. Naturally we only meet with

these cases in patients over 30 who have never worn glasses. These cases are, to my mind, a further proof of the existence of partial contraction of the ciliary muscle.

The cases above mentioned occur in astigmatism "with the rule." In astigmatism "against the rule" the dynamic astigmatism does not have the same tendency to become fixed. In presbyopic cases "against the rule" the lens astigmatism commonly disappears.

LATENT ASTIGMATISM.

At times we find cases in the transition stages between these changes; that is, with increased tonicity in the fibers of the ciliary muscle, but no permanent change in the shape of the lens. These cases belong to the class of so-called "latent astigmatism," and if a mydriatic is used a certain amount of lens astigmatism is manifest, though after the mydriatic has ceased its effect the tonicity of the fibers in the meridian of contraction may again compensate for the corneal astigmatism.

FACTORS IN TREATMENT.

In general, then, we have in the treatment of every case to consider the following factors, and, where absolute measurement fails us, to assign as nearly as possible a correct valuation in accordance with our judgment of the individual case: 1. Corneal astigmatism. 2. Lens astigmatism: a, static; b, dynamic. 3. The degree of compensation. 4. The factor in the error which is producing symptoms.

Obviously the last point is the end and aim of our efforts as practical ophthalmologists, and the relief of the irritative symptoms is the only question which greatly interests the patient.

TESTS EMPLOYED.

For determining the above mentioned points there are only two positive tests: 1, the ophthalmometer for the corneal astigmatism; 2, the shadow test for the total astigmatism. It may be urged against the ophthalmometer that the posterior surface of the cornea will modify its reading, but that this modification must be very slight indeed is shown by the well-substantiated assertions of Baker.⁵ From a practical standpoint I never consider this factor. The shadow test, taken by itself, gives no idea of the proper proportions of the various factors to be considered, and, while undoubtedly of great value in association with other tests, is of limited value when taken alone. It must always be done with the aid of a mydriatic. Its most enthusiastic advocates lay great stress on the accurate determination (if not correction) of the total refractive error, and this point of view might be the correct one if we were dealing only with the eyes of the young in which the original error is not modified. In practice we find all sorts of modifying circumstances, with the changes in the ciliary muscle and lens above mentioned. In brief, the question must be approached from the standpoint of the physiologist and the pathologist (if one may use the term in this connection) rather than that of the anatomist.

As Hess says in his masterly paper read before this Section last year:⁶ "Here" (i. e., under mydriasis)⁴ "the optic conditions are so different from the normal that it is impossible to come to a conclusion as to the normal refraction of the patient's eye."

1. Refraction and Accommodation of the Eye, p. 302.

5. Norris and Oliver's System, 1, 138.

6. THE JOURNAL A. M. A., July 20, 1907, p. 230.

The subjective tests with the trial lenses I believe to be perhaps the most important in our list, when based on our other measurements, and the technic of applying them is very important. It hardly seems necessary at the present time to go into details on this point, but I may say that the "fogging" method has been generally unsatisfactory in my hands, and I much prefer to test with cylindrical lenses in the axis of the corneal astigmatism, gradually increasing the strength of the lenses and adding only the required spherical lens to bring the visual acuity to the point where finer changes are more noticeable to the patient. I then vary the axis to find any modifications that may exist; if I am unable to find the correction which gives relief, I use a mydriatic and obtain a reading of the total error.

The actual lens prescribed depends on the judgment of the various questions above mentioned, taken in connection with the general muscular constitution (as bearing directly on the constitution of the ciliary muscle), the needs of the individual, and the existence of any local complications—as strabismus, heterophoria, etc., which need not be considered here. I do not underestimate the value of the ophthalmoscope in the treatment of refractive errors, but its bearing in the present question is only to give a close approximation to the total spherical error, which, of course, we must know, and it is of little value in the actual determination of the amount of astigmatism.

To obtain the lens astigmatism, we subtract the corneal astigmatism from the total, as obtained by either of the above mentioned methods. The proper appreciation of the true cause of the lens astigmatism and of the factors producing the visual disturbance will depend not so much on mere figures as on the clinical conditions bearing on the case. To particularize, it is necessary to take up *seriatim* the different forms of astigmatism:

HYPEROPIC ASTIGMATISM.

The majority of cases of hyperopic astigmatism will fall under one of the following general classes:

1. *Low Degrees of Corneal Astigmatism, Completely Compensated by the Lens, Axis 90° or Thereabouts.*

These cases occur at any age, give no symptoms, and accept no cylindrical glasses with or without a mydriatic, and have normal vision with a corneal astigmatism of not more than one diopter, usual axis 90°, symmetrical in the two eyes. They form the largest class of cases. We see them only incidentally, in the course of treatment of other eye conditions—inflammations or presbyopia—and, of course, they require no correction. The compensating astigmatism of the lens is static; whatever it may have been originally. My own feeling is that a large proportion of such cases, perhaps the great majority, begin as dynamic lens astigmatism, and that the efforts of the ciliary muscle are purposeful, and ultimately lead to full correction without the aid of cylindrical glasses.

2. *Higher Degrees of Corneal Astigmatism, with Partial Regular Compensation by the Lens, Axis 90° or Thereabouts.*

Under this heading we have the largest class of cases coming to us for treatment. The lens astigmatism occurs in the same axis—or very nearly the same axis—as the corneal astigmatism, and amounts to between 0.50 and 1 diopter. It is for this reason that we have the arbitrary rule of subtracting 0.50 diopter from the

reading of the ophthalmometer in prescribing lenses, a rule which seems unfortunate as leading to a certain amount of misapprehension, though, in fact, our other tests usually give us approximately this result.

These cases, almost without exception, have a diminution of the visual acuity for distance (the amount depending on the degree of astigmatism) with asthenopia. Even small amounts of astigmatism are not properly to be called latent, though the meridional contraction occurs only at intervals when the patient is looking at the test card, and in most instances need not occur at all if the cylinders are carefully tried. By subtracting the total astigmatism (manifest with the trial lenses) from the corneal we have the lens astigmatism, and whether this be static or dynamic will depend on the severity of the asthenopia, the age of the patient, the length of time that the eyes have gone uncorrected, and the general muscular constitution of the individual.

After the age of 35 the compensating astigmatism is almost invariably static, and we may see even high degrees of compensation at this time; that is, 1.50 to 2 diopters, where glasses have never been worn and where the muscles have been allowed to develop gradually without undue forcing. In such cases, even under the influence of a mydriatic, the manifest astigmatism is not increased. Before 35, or thereabouts, the judgment of the character of the lens astigmatism is more difficult, and I have come to depend to a great extent on the finding of tender spots over the ciliary region, frequently in the meridian of contraction, when a dynamic astigmatism exists. If I find these tender spots, I suspect the astigmatism to be latent or dynamic, and I prescribe a mydriatic, both for accuracy in obtaining the test and for its physiologic action on the contracted fibers of the ciliary muscle. In most instances, the astigmatism will be found to be dynamic and needing partial or total correction, depending on the clinical features of the particular case, i. e., the amount of use of the eyes, the length of time since glasses have been worn, the age of the patient, and the general muscular constitution. One should be very careful in this connection not to overcorrect, for overcorrection is productive of much more irritation than undercorrection. Where no irritation of the ciliary muscle can be discovered, it seems unnecessary to use a mydriatic, and in practice I do not find that I am led into error through this line of procedure.

3. *Low Degrees of Corneal Astigmatism with Irregular Compensation by the Lens.*

This class is composed almost entirely of cases in which the corneal astigmatism is less than 0.75 diopter. It occurs most frequently in cases where the corneal astigmatism is not symmetrical; that is, one cornea may have a 0.50 diopter of astigmatism, the other none. In such cases the axis of the total manifest astigmatism represents a mean between the cornea and the lens, whose astigmatism, either from its original static condition or through faulty accommodative efforts, lies in an entirely different axis from the corneal. Such cases are much prone to vary. The astigmatism will appear and disappear, the axes will change from time to time, even where we use a mydriatic and endeavor to put them on more permanent bases.

In these cases, as in the former, I do not use a mydriatic, unless I have evidence of muscular cramp, as shown by tender spots over the ciliary muscle. I prefer to correct the manifest astigmatism after not less

than two careful tests with the trial lenses. Unless there is a definite indication that the distance vision is accomplished through irritating accommodative effort, I prescribe the glasses only for the near work, and I often find that under this form of treatment the ciliary muscle adjusts itself, compensation is regained, and the glasses may be laid aside.

In this class of cases we frequently see the results of coordinated effort in the ciliary muscles of the two eyes; that is, where we have no corneal astigmatism in one eye and 0.50 diopter, axis 90° in the other eye, the same meridians will contract to such a degree that our final astigmatism will read axis 180° in each eye—say 0.50 diopter, axis 180° , in one eye, and 1 diopter, axis 180° , in the other eye, with 0.50 diopter or corneal astigmatism, axis 90° . In other words, the compensation in the eye with the 0.50 diopter of corneal astigmatism has overshot the mark and given us an excessive lens astigmatism.

4. Corneal Astigmatism with the Axis at 180° or Thereabouts.

In this class of cases, as is well known, the symptoms are very much more severe, compensation is much less apt to occur, and the lens astigmatism is frequently in excess of the corneal. Here we frequently find the lens astigmatism to be static, and the correction must be worn constantly. The reason for the increased difficulty of compensation in this class of cases over the preceding class is naturally to be looked for in a greater normal tonicity of certain fibers of the ciliary muscle over certain others, but so far we have no anatomic investigations to help us out on this point.

5. Cases of Simple Lens Astigmatism.

In these cases the cornea shows no astigmatism, and the astigmatism is confined to the lens. It may be as high as a diopter, is accompanied by severe symptoms, and occurs most frequently below the presbyopic age. It is very desirable to use mydriasis in these cases, where even a small amount of muscular tenderness exists, as there is every evidence that the lens astigmatism is most frequently due to faulty ciliary contraction, and that if we keep our correcting lens a little under the full dynamic astigmatism with suitable management of the work done by the ciliary muscle, the astigmatism will ultimately disappear.

MYOPIC ASTIGMATISM.

In myopic astigmatism, we have, in general, a weaker ciliary muscle, and the compensating lens astigmatism is much less purposeful in its character than in hyperopic cases, as we should expect. While in the nature of the case there can be no constant correction of the astigmatism by the ciliary muscle, still in low degrees, unaccompanied by spherical error, we commonly find an attempt at correction or a contraction of the meridional fibers of the ciliary muscle, produced largely by certain habits in reading.

It must be remembered that within the far point of the meridian of greatest refraction (the most myopic), the only way the astigmatism can be reduced by the ciliary muscle is by correction in the opposite meridian, making both meridians myopic in the same degree, if the astigmatism is not too high; or reducing the astigmatism in the same way, if it is too great to be corrected entirely. We have, then, the same source of irritation as in hyperopic cases, but with a relatively weaker ciliary muscle, whose weakness depends on the amount of

spherical myopia, etc. It is for this reason that we so frequently find severe asthenopic symptoms in myopic astigmatism, and that such cases so frequently simulate simple myopia in the distance test. Low degrees will almost always accept spherical lenses for distance, if the same be added until both meridians are corrected, which, of course, leaves one meridian overcorrected. For this reason, I always correct the astigmatism before I add the full spherical lens, and I find very few cases of plain spherical myopia, even where the error is as high as 10 diopters.

Myopic astigmatism occurs in these general classes:

A. Corneal Astigmatism, with Partial Regular Compensation by the Lens at the Near Point, Axis 180° or Thereabouts.

These cases have always marked diminution of distance vision with marked asthenopia for the near point on account of the meridional contraction of the ciliary muscle, as well as other factors, which we need not consider here. Low degrees may simulate a simple myopia—a patient may fail to notice an improvement in reading with cylindrical glasses—and, yet, they require full correction of the astigmatism, both far and near, if the ciliary muscle is to obtain its greatest power, and if the asthenopia is to be relieved entirely. On account of the difference in the constitution of the ciliary muscle and the fact that the dynamic astigmatism occurs only intermittently, compensation, as in hyperopic cases, does not occur, and full correction should be worn constantly.

If there is difficulty in inducing the patient to accept the cylindrical glasses called for by the corneal astigmatism, minus a certain amount for the lens (0.25 to 0.50 diopter), or if tenderness exists in the ciliary region, a mydriatic should be used, and the total static astigmatism be determined. It should never be forgotten that low degrees of this class may be due to overcontraction of the ciliary muscle in hyperopic astigmatism, simple or compound, but these cases have usually marked symptoms, and, moreover, are rather rare, errors of diagnosis in this connection being generally due to faulty technic with the trial case. The clock dial is of considerable value in the testing of these cases, for the lens astigmatism is apt to assume its static amount in the distance test, undisturbed by irregular ciliary contractions. It must be remembered, however, that where the eyes have been used without glasses for near work, especially in low degrees of spherical error, and where the muscular constitution is good, there may be some modification of the astigmatism at the distance, and we should not pay too much attention to any single test, but rather give weight to the preponderance of evidence in determining the full amount of astigmatism.

B. Low Degrees of Corneal Astigmatism, with Irregular Modification by the Lens.

These form a very large class, perhaps as large as the preceding. They show great variations in axes and amounts from the corneal astigmatism, which is usually "off axis," and not symmetrical in the two eyes. The principles that have already been discussed in the two previous classes of cases apply with equal force here, and it should especially be borne in mind that the lens astigmatism is so much less purposeful than in corresponding cases of hypermetropic astigmatism that the corneal reading, while important, is very little guide to the total astigmatism. I always try cylinders in the axis of the corneal astigmatism first, but if the indications are that the case belongs to the class under dis-

cussion, I do not hunt for the proper axis with the test lenses, but prefer to proceed at once to the clock dial test. This is apt to be of value, as dynamic astigmatism plays a relatively small part in such cases in far sight, and determination of the full static error is important.

C. *Lens Astigmatism Pure and Simple.*

In this class there is no corneal astigmatism, and the astigmatism is located entirely in the lens. It rarely exceeds 1 diopter, is static in character, has the same characteristics, and requires the same treatment as in the preceding class. It is very doubtful if a dynamic myopic astigmatism ever develops from a hypermetropic case, such changes being usually due to lengthening of the eyeball.

MIXED ASTIGMATISM.

These cases practically all belong to one class. The corneal astigmatism is high and "with the rule," in the vast majority of cases; in fact, mixed astigmatism "against the rule" has been with me one of the greatest of rarities. The distance vision is relatively good, when we consider the amount of the astigmatism, but asthenopia is severe. No complete lens compensation is possible, but almost invariably severe cramps of the fibers in the hypermetropic meridian exist, and are not at all readily overcome by any amount of care in testing with the trial lenses. Variations in the axis of the lens astigmatism from the corneal are uncommon, and when they do exist are of low degree, usually not more than 10° or 15° , and frequently less. Almost invariably we find a reduction of the hypermetropic meridian which is dynamic in character, and to my mind the only proper way to deal with such cases is to use a mydriatic, determine the full amount of astigmatism, and have the glasses put on before the effect of the mydriatic has passed off. We have here a condition of the ciliary muscle which may be considered a pathologic one, and the mydriatic is necessary, as much for a restoration of the fibers to the normal as it is for diagnostic purposes. Of course, this applies only to cases in which classes have not been worn. Where the ciliary muscle is in better condition, it is frequently possible, by care in the technic of the trial case, to ascertain the astigmatism without a mydriatic. Where the full correction has been prescribed with the assistance of a mydriatic, the case should always be studied subsequently and the action of the ciliary muscle noted, and any irregularity in the focus met by an appropriate change of lens.

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DISCUSSION.

DR. G. C. SAVAGE, Nashville: I do not deny that there is such a thing as lenticular astigmatism; I do deny that there is any such thing as partial contraction of the ciliary muscle. If there is a lenticular astigmatism, what brings it about, and if it is due to partial contraction of the ciliary muscle, why is it that atropin will not suspend it? Bowman's muscle has been forgotten. It is supplied by nerve fibers, as every muscle is, but not by the third-nerve fibers. Bowman's muscle fibers run meridionally and they must be there for a purpose. I believe that Bowman's muscle is supplied by the cervical sympathetic. Under the guiding influence of some faculty of the mind this muscle does the duty for which it was made, and if Bowman's muscle does anything at all it is the tilting of the lens. What will that do? Now if I have a +3.00 lens in my hand and tilt it on the horizontal axis 45 degrees the focus for rays in the horizontal plane will be, say, 13, and for those in the vertical plane $6\frac{1}{2}$ inches. Now we have such power of tilting the lens of the eye but not through so great an arc. This tilting is done by the proper fibers of Bowman's muscle.

and for the purpose of correcting, in part or wholly, the corneal astigmatism. In my own case I suffered when coming up to middle life and nothing conquered my astigmatism except time. The first cylindrical lens given me was plus 0.60 D. and atropin developed no more. A few years later I had to have 0.75 D. and later a 1.00, 1.25, 1.50 D. and now 2.50 D. Eighteen years ago my corneas were measured for the first time with the ophthalmometer and I had 2.50 D. of astigmatism. Bowman's muscle also serves to adjust the lens in the new-born child. If its plane is not at right angles to the visual axis the muscle fibers contract in one part or another to straighten the lens. The purpose of that muscle is to prevent lenticular astigmatism, when there is no corneal astigmatism, as well as to neutralize an existing corneal astigmatism.

DR. LUCIEN HOWE, Buffalo: We may recognize lenticular astigmatism by means of the entoptic images, first described by Purkinje. These were first shown to me by Tscherning with his ophthalmophacometer. That is a laboratory instrument, but it can be made useful clinically by slight alterations. Thus we can take out the prism from the ordinary Javal-Schiötz ophthalmometer by unscrewing the projection in front of the disc and lifting out from the tube the part which holds the prisms. That converts the ophthalmometer into a telescope like the ophthalmophacometer. If we also attach a small electric light immediately below the axis of the tube, on looking through the telescope at the eye we see two reflections of this light. One of these reflections, large and distinct, is of course from the anterior surface of the cornea; the other reflection, small but bright, is from the posterior surface of the lens. If we revolve the tube of the telescope in the usual way, then, as the small electric light revolves, also, the reflection from that light which comes from the posterior surface of the lens describes a distinct circle around the reflection of the light from the cornea, in all cases in which the axis of the lens is practically the same as the axis of the telescope, that is to say, in all cases in which there is no tipping of the lens with the consequent astigmatism. If the lens is tipped forward or sidewise, however, then, when the tube of the telescope with the electric light is revolved in the usual way, the reflection of the light which comes from the posterior surface of the lens does not describe a circle around the reflection from the cornea, but it does describe an ellipse. When the lens is tipped forward, the long diameter of that ellipse is horizontal; and when the lens is tipped sidewise the long diameter of the ellipse is vertical. In dynamic astigmatism due to partial contraction of the ciliary muscle, the iris may dilate irregularly by ordinary doses of atropin, but this can be seen more frequently if we use about 0.00001 gram. This should be applied in the little discs. The pupil then may dilate as an ellipse, indicating unequal contraction.

DR. WALTER L. PYLE, Philadelphia: No better evidence of the necessity of using cycloplegics in the examination of the refraction of the eye can be offered than the facts set forth by Dr. Thomson and the subsequent speakers. There is no doubt in my mind of the frequency of partial contraction of the ciliary muscle, and in cases of long standing it is perhaps not possible to produce full cycloplegia at the first examination for refraction. By constant use of the initial optical correction, a gradual unfolding and relaxation of the spasm ensues, and only after several repeated corrections of refraction, under cycloplegia, possibly extending over several years, may the full static astigmatism be determined and corrected. These facts explain in part the great divergence of opinion relative to the efficiency of the different cycloplegics. I have frequently detected a greater amount of ametropia at a second refraction under homatropin and cocain than at the initial examination under the stronger cycloplegics, such as atropin and duboisin. The great practical lesson from these observations is the necessity of periodical examinations of refraction and changes of lenses whenever indicated by recurrence of local or reflex asthenopic symptoms or evidence of refractive changes. It should be remembered that when such changes occur they may give rise to symptoms quite as annoying as the initial discomfort that led the patient to seek ophthalmic treatment. It is a well established fact that the compensatory ciliary efforts in the involuntary attempts to correct astigmatism are far more

provocative of the manifold symptoms included under the general term "eyestrain" than are the similar spastic conditions in simple hyperopia.

DR. A. I. DEEDIGER, Chicago: Noting particularly the difference in correcting errors of refraction without and with a mydriatic, and the changes that frequently take place in the amount of correction and also the changes in the axis of the cylinder where there is astigmatism, I decided some years ago to study some of these cases that vary considerably. A change of the axis, even of 5 degrees from the vertical or horizontal to the oblique, has made a remarkable difference in the relief given to the patient. A man, aged 43, vision before atropin was used, 20/15 (above normal), accepted minus 0.25 in each eye with no difference in vision. He had 6 degrees of right hyperphoria which I corrected by an operation on the superior muscles of the right eye. Using atropin for three days there was vision in both eyes of 20/30; with the right eye $+0.25 \text{ C} + 0.50 \text{ vision} = 20/30$. I prescribed full correction and he wore glasses with comfort until Aug. 27, 1907, when he had recurrent headaches. Under atropin vision was found to be 20/30 and the right accepted $+0.75 \text{ C} + 0.50 \text{ C}$, axis 45, vision $= 20/20$; left eye, $+0.50 \text{ C} + 0.50 \text{ C}$, axis 120, vision $= 20/20$. These were worn until April, 1908, when the patient returned again, complaining of similar attacks. Atropin was used again and this time vision reduced to 20/40. Right eye accepted $+0.25 \text{ C} + 0.75 \text{ C}$, axis 45, vision $= 20/20$; left eye $+1 \text{ C} + 1 \text{ C}$, axis 120, vision $= 20/20$. There was more astigmatism and more hyperopia in both eyes. One of the most important things is to give full correction after the age of 30, especially for close work.

DR. A. R. BAKER, Cleveland: I do not think that these repeated statements, "I do not use mydriatics," should be endorsed. You might as well try to fit a man with a suit of clothes while he is running down the street as to try to fit glasses without a mydriatic.

DR. E. C. ELLETT, Memphis, Tenn.: I recently saw a case in which rapid changes took place in the astigmatism. Mr. P., a preacher, aged 39, a hard worker and a man who took little exercise, was seen in March, 1908, complaining of recent poor vision. He saw 20/60 in each eye, unimproved by glasses, and read J. xii with O. D., and J. vi with O. S. The nerves showed distinctly veiled edges, but no measurable swelling, no hemorrhages, no exudation. The ophthalmometer showed plus 0.50 D., regular astigmatism with the rule. The fields were normal. He complained of indigestion and constipation. His tongue was brown and furred, his liver large and tender, the spleen slightly enlarged and the other organs normal. The urine showed marked indicanuria. He slept poorly, was inclined to be moody and depressed, and his general condition was poor. I am indebted to Dr. Buford for the notes as to his general condition. In less than one month his vision was normal, with glasses, after treatment by massage, diet, washing the stomach, high enemata and plenty of water internally. Successive tests of the refraction showed:

March 30: O. D. $+1 \text{ cyl. ax. } 120^\circ$. O. S. $+1.50 \text{ cyl. ax. } 180$.
April 1: O. D. $+1.50 \text{ cyl ax } 130^\circ$. O. S. $+1.50 \text{ cyl. ax. } 180$.
April 3: O. D. $+2.50 \text{ cyl. ax. } 125^\circ$. O. S. $+ .50 \text{ cyl. ax. } 180$.
April 17: O. D. $+ .75 \text{ cyl. ax. } 90^\circ$. O. S. $+ .50 \text{ sph.}$

All these tests were without a mydriatic. When last examined, on April 17, the correction indicated gave 20/20 full in the right and partly in the left, and J. i in each eye. The nerves were not yet perfectly clear.

DR. A. E. DAVIS, New York: I do not believe that lenticular astigmatism is due to partial contraction of the ciliary muscle. I do not see why the ciliary muscle should have a selective action in one set of cases, in corneal astigmatism with the rule, for instance, to neutralize part of the corneal astigmatism; and yet in another set of cases, in corneal astigmatism against the rule, to increase the corneal astigmatism, as we know to be the case from actual experience. I consider that Dr. Thomson makes one error in regard to the arbitrary subtraction of 0.50 D. from the reading of the ophthalmometer in astigmatism with the rule, and in the addition of 0.50 D. in astigmatism against the rule. The arbitrary addition or subtraction of a certain amount, say 0.50 D., should not be practiced; but after the ophthalmometric reading is made, sub-

jective and objective tests should be made, guided by the ophthalmometric reading; and the difference between the glass accepted by the patient and the glass indicated by the ophthalmometric reading is the amount that should be subtracted or added, as the case may be. This difference may be 0.25 D., 0.50 D. (as is usually the case), 0.75 D., or even 1 D.; and in astigmatism with the rule it is subtracted from the amount indicated by the ophthalmometer, while in astigmatism against the rule it is added. Now this very difference in the corneal astigmatism as measured by the ophthalmometer and the total astigmatism as represented by the cylindrical glass accepted is supposed to be due to the lenticular astigmatism, which lenticular astigmatism Dr. Thomson thinks to be due to unequal and selective action of the ciliary muscle. But this I do not believe to be the case, because, if we assume the lens to be tilted slightly on its vertical axis either to the right or the left, we can easily understand how it neutralizes part of the corneal astigmatism when it is with the rule, and how it adds to it when it is against the rule. According to the extent of the tilting it may neutralize 0.25 D., 0.50 D., 0.75 D., or even 1 D. of the corneal astigmatism, as above mentioned, but this must be found out by actual tests and can not be arbitrarily added or subtracted. In my experience this is the true explanation of lenticular astigmatism as opposed to Dr. Thomson's explanation, as he considers it due to unequal contraction of the ciliary muscle. I am of the same opinion in this regard as Hess and Bull, both of whom believe that lenticular astigmatism is accounted for by the tilting or slight displacement of the lens.

I advocate testing for glasses, in the majority of cases, without the use of cycloplegics. I was taught to use atropin or some other cycloplegic in every patient under forty years of age, but I have come to abandon their use almost altogether since the introduction of the ophthalmometer. In some cases it may be necessary to use them (as in spasm of accommodation or in children under ten years of age), and then I use the powerful cycloplegics, and do not trifle with doubtful ones, such as homatropin.

DR. ALBERT E. BULSON, JR., Fort Wayne, Ind.: As ophthalmologists we deserve severe criticism for using the terms "mydriatics" and "cycloplegics" synonymously. A cycloplegic is always a mydriatic but a mydriatic is not always a cycloplegic. To be certain that we have determined the static refraction of an eye requires cycloplegia, and without cycloplegia results are apt to be contradictory. The correction of the full static refraction is seldom borne comfortably by the patient, but a knowledge of the full static refraction is necessary in order to estimate properly the correction to be given. Occupation, temperament, and the physical condition of the patient will play an important part in arriving at conclusions as to the amount of the static refraction to be corrected.

DR. EDGAR S. THOMSON, New York City: I do not ignore the static astigmatism of the lens which to my mind accounts for some of the differences between astigmatism with the rule and against the rule. Further than that I think we have not data enough to decide that question. To my mind it is not a sweeping question as to whether we shall use cycloplegics or not. I do not hesitate to use them when necessary; in fact I always use them when I consider it necessary; but the point I make is that we must study the condition of the ciliary muscle. Is it compensating? Is it of normal tone or is it in a condition of cramp? If in a condition of cramp, we shall find local tenderness. I do not think that the matter can be put on the ground that no good work can be done without a cycloplegic or no good work with it. I am still unconvinced by Dr. Savage's arguments, but I admit that we have no scientific data and it seems hardly worth while to discuss theories. To my mind the important point is this, that we do not find high degrees of compensating astigmatism in presbyopes and if compensation were due to tilting of the lens we should expect it to appear as frequently in presbyopes as in the young. I believe that the gradual failure of compensation, in such cases as Dr. Savage has cited, is due to advancing nuclear sclerosis and is an indication in favor of the theory of partial contraction.