ARTICLE XXI.

WHAT CONSTITUTES INSUFFICIENCY OF THE INTERNAL RECTI MUSCLES?

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DURING several years a conviction has been gradually developing in my mind that I did not know what constitutes insufficiency of the internal recti muscles, or, at least, that I did not know where the line between sufficiency and insufficiency should be drawn. When, in seeking to account for the existence of asthenopia, I discovered by the usual means a considerable degree of hypermetropia or of astigmatism, I felt that I had found something which was definite and real, and I had little doubt that the correction of this defect would be followed in due time by the disappearance of the asthenopic symptoms; but, on the other hand, when, failing other causes, I was led to examine the state of the muscles of convergence, and by means of the tests usually relied upon, discovered, according to the accepted standards, insufficiency of these muscles, I felt that I was dealing with something which was far less definite, and I could not escape the suspicion that the therapeutic measures which this discovery prompted me to take were, perhaps not unfrequently, directed against an evil which had only an imaginary existence.

So far as I can account for this state of mind, it was due, first, to the fact that I seldom sought for insufficiency of the internal recti muscles without finding it, unless hypermetropia existed; secondly, to the frequency with which I observed the disappearance of asthenopic symptoms without any diminution in the apparent insufficiency of the muscles; and, thirdly, to the contradictory character of the results which I obtained in many cases from the different tests upon which we are taught to rely to determine the existence and to measure the amount of this anomaly.

The important influence which errors of refraction exert upon the behaviour of the muscles of convergence; the necessity of correcting such errors or of allowing for their influence, in applying the tests for insufficiency; and the propriety of distinguishing between real insufficiency or weakness of the internal recti-muscles and the apparent insufficiency which is so commonly associated with myopia, and which is due to disturbance of the normal relation between accommodation and convergence, were forcibly impressed upon my mind some years ago, through a study of the behaviour of my own myopically formed eyes, and in a paper entitled "An endeavour to show that insufficiency of the internal recti muscles and myopia have been erroneously associated; and that the muscular asthenopia of myopia is not the result of such insufficiency, but of the anomaly of refraction," published in the *Am. Journal of the Med.*

[1] Read before the American Ophthalmological Society at its annual meeting in Newport, R. I., July, 1881.

Sciences, in January, 1874, I dwelt at some length upon these points. At that time I argued that the Graefe tests for insufficiency of the internal recti muscles, though trustworthy when applied to emmetropic eyes, are calculated to give deceptive results in ametropia, because of the disturbance of the normal parallelism between accommodation and convergence, unless as preliminary to their application the precaution is taken to correct the error of refraction. That, owing to the disposition which ametropic eyes always exhibit to restore this normal parallelism, an effort to do so is made so soon as the production of vertical diplopia annuls the still stronger desire for single vision, and that as a result of this the vertical prism tests show "in hypermetropia, an excess of power in the internal recti muscles which is not real," and, "in myopia, an insufficiency which is only apparent," being merely the expression of "the ever present, but for the moment unrestrained desire, to exact as little work of the internal recti as is at the same time required of the ciliary muscles." In support of this view I mentioned that an apparent insufficiency of 12°, which my own eyes, with $M\frac{1}{16}$, exhibited at 8″, disappeared entirely with total correction of the myopia, diminished with partial correction, and was increased by convex glasses; and, further, that when the experiment was tried of placing before one eye a convex glass, and before the other a concave glass, which more than neutralized the myopia, so that objects could not be seen distinctly at the same time with both eyes, the images of the dot in the vertical diplopia test changed their positions in such a manner, as to indicate excess of power in the internal recti when the dot was seen distinctly with the over-corrected eye, with strained accommodation, and marked insufficiency when looked at, with relaxed accommodation, with the eye before which the convex glass was placed.

Two other possible sources of error in Von Graefe's dot and prism test, which were detected during my experiments, were also pointed out, and a means of getting rid of them suggested. The relation between accommodation and convergence being so intimate, it becomes important that during the examination the eyes should be accurately accommodated for the distance at which the test object is held. Now the round dot of the Graefe test, since it remains a round dot, and is seen almost as distinctly whether brought exactly to a focus upon the retina or not, does not offer a sufficient incentive to accurate accommodation, and is, therefore, ill-adapted to the purpose for which it is employed. For this reason the substitution of a star for the dot was proposed—a cross, which otherwise might have answered still better, being discarded because of the confusion to which it would be likely to give rise should astigmatism happen to be present. The other source of error lies in the undue length of the vertical, bisecting line. The two images of this line overlap; and this was found in a measure to annul the influence of the vertical diplopia, an involuntary inclination to blend the overlapping portions of the images being felt.

The omission of the line, therefore, since it is not an essential part of the test, was recommended.[1]

[1] An interesting and instructive article by Dr. E. G. Loring upon "Tests for the Insufficiency of the Recti Interni Muscles," which appears in the Transactions of this Society for 1868, has been brought to my notice, since the preparation of this paper was begun, by my friend Dr. Russell Murdoch. In this article Dr. Loring discusses the trustworthiness of the several tests proposed by Von Graefe, and especially considers *whether the vertical diplopia tests do away with all voluntary control over the muscles of convergence*, and *whether the prism which reduces crossed images to the same vertical line expresses the whole amount of the insufficiency of the interni*. His conclusions upon these two points are, that the production of vertical diplopia does not always prevent such control, and that the prism which reduces the images to the same vertical line, in some instances, indicates only a part of the total insufficiency. In support of the former conclusion, he mentions a case in which a patient during the application of the test was able to produce at will either crossed or homonymous images in both near and distant vision, and cites his own ability to do this with the test card at twelve inches. This faculty of changing the position of the images is, I think, due rather to voluntary control of the accommodation than to direct command over the internal recti muscles, the alteration in the direction of the visual lines being brought about by increasing at one moment and diminishing at another the tension of accommodation; at all events the ability to control the position of the images, without a corresponding change of accommodation, must be of extremely rare occurrence. We have it in our power, therefore, to prevent this perplexing accident, by insisting that the test object be accurately accommodated for; and this the change in the form of the object which I have proposed renders more easy of accomplishment.

The second conclusion is sustained by reference to cases which he had frequently met with, in which "after we have brought the images from being crossed into the same vertical line, we can go on adding prisms, sometimes those of considerable degree, and yet the images remain exactly over each other, instead of becoming homonymous." The explanation offered of this occurrence, that it is due to the existence of *latent* insufficiency, comparable to latent hypermetropia, does not seem to me very satisfactory. In the first place, latent insufficiency to be comparable to latent hypermetropia should be insufficiency which cannot be immediately rendered manifest by glasses, whereas the insufficiency which Dr. Loring describes as latent, expressed by the difference between the weakest prism which causes the images to stand in a vertical line, and the strongest which does not induce homonymous separation, is brought out at once by this means. Furthermore, how does this explanation help us to comprehend the singular circumstance, that with each increase in the strength of the prisms the latent insufficiency is brought out, or the internal recti muscles yield, to exactly such an amount as to keep the images directly one above the other? In hypermetropia, exactly a forty-eighth, next a forty-second, and then a thirty-sixth is rendered manifest by the application of glasses, because the ciliary muscle is prompted each time to yield to just that extent to accomplish a definite purpose—the maintenance of distinct vision; but why should the internal recti muscles, with apparently no definite purpose to be served by keeping the images in the same vertical line, yield in the regular manner described? Dr. Loring's suggestion of latent insufficiency certainly affords no explanation of this. The true explanation, it seems to me, is to be found in quite a different direction—in the overlapping of the images of the unduly long bisecting line of the test, to which I have referred as a possible source of error, and the obviation of which I have proposed because of the likelihood of its giving rise to just such confusing results. Suppose in a case of insufficiency of considerable degree this inclination to fuse the overlapping portions of the lines, exists, the images being widely separated this disposition would probably remain in abeyance, but so soon as they were brought somewhat nearer together, by a

Though these several sources of error in the determination of insufficiency of the internal recti muscles attracted my attention early, and though subsequently they were kept constantly in mind, and in practice were guarded against by the adoption of the precautionary measures to which I have referred,[1] a feeling of uncertainty as to the trustworthiness of the results which I obtained in dealing with this condition has, as I have said, with the increasing experience of the last few years forced itself, more and more, upon me. The disappearance of asthenopic symptoms in certain cases, without any diminution in the insufficiency of the internal recti muscles, upon which they were supposed to depend, and the existence of which had been demonstrated by the usual tests, especially suggested the inquiry, *whether, even in emmetropia and with accommodation properly regulated, a considerable relative divergence of the visual lines might not occur in connection with vertical diplopia, and still no insufficiency of the internal recti muscles be present*, or, if this be interpreted as proof of insufficiency, whether this so-called insufficiency might not exist to a marked degree, and the eyes be none the worse for it.

In order to determine whether or not this was the case, I concluded to examine with especial reference to this point a number of strong-eyed, non-asthenopic individuals; and in selecting suitable subjects for this purpose, to make the experiment more decisive, I chose only those whose occupations led to frequent use of the eyes in near vision. My examinations were not confined to emmetropic eyes, but whenever errors of

prism representing perhaps only one-half of the true insufficiency, they would be fused by an unconscious effort. Now it is evident that with each increase in the strength of the prisms, until the one was reached which truly represented the insufficiency, the fusion of the lines would be rendered easier of accomplishment, and that after this point had been passed, the prisms might be progressively increased for some time before this tendency would be again annulled by a too wide *homonymous* separation of the images. In this persistent blending of the overlapping images of the line, it is evident, is implied exactly such exceptional behaviour of the interni with prisms of different strength as Dr. Loring describes; and which exceptional behaviour I may add, in confirmation of this view, I have never observed with the test modified as I have proposed. While, therefore, endorsing much that is contained in Dr. Loring's article, especially what is said concerning the influence of errors of refraction in modifying the results of the Graefe tests, I am compelled to differ with him as to the significance of these two observations, to which he especially directs attention.

[1] During the discussion which followed the reading of this paper Dr. R. H. Derby, formerly a pupil of Von Graefe, stated that in 1869 Von Graefe, himself, had modified his original vertical diplopia test for insufficiency in almost the identical manner which I afterwards suggested (in my paper in the *Am. Journal Med. Sciences* in 1874), and for reasons almost precisely the same, and that he had described these modifications in an article in the *Klinische Monatsblätter für Augenheilkunde*, in 1869. It would seem that the suggestions contained in this paper of Von Graefe, referred to by Dr. Derby, have attracted comparatively little attention, at least they are not alluded to in any text-book upon diseases of the eye with which I am familiar; even Soelberg Wells, Von Graefe's pupil and disciple, does not mention them, but describes only the original test. Dr. Derby's mention of them at Newport, last summer, first brought them to my notice.

No.	Sex	Age	Refraction.	Vision.	Result of Cover Test at 12″.	Results of Prism Tests. At 12″.						At 20′.						Remarks.
									With error of refraction corrected.						With error of refraction corrected.			
						Insuf. intern. recti.	Insuf. extern. recti.	Intern. recti overcome.	Insuf. intern. recti.	Insuf. extern. recti.	Intern. recti overcome.	Insuf. intern. recti.	Insuf. extern. recti.	Intern. recti overcome.	Insuf. intern. recti.	Insuf. extern. recti.	Intern. recti overcome.	
1	F.	31	Hm. $\frac{1}{60}$	$\frac{20}{xx}$	No perceptible movem't.	3°	....	14°	4°	....	11°	0°	...	10°	1°	....	8°	Has strong eyes. Reads and sews a great deal, and has never worn glasses.
2	F.	11	Hm. $\frac{1}{48}$	$\frac{20}{xx}$	No perceptible movem't.	2	....	34	3	....	28	0	....	25	0	....	18	Never complains of eyes; goes to school; does not wear glasses.
3	F.	23	Hm. $\frac{1}{48}$	$\frac{20}{xx}$	Not tried.	6	....	46	7	....	....	0	....	18	0	....	....	Eyes "very strong." Reads and sews a great deal, and has never worn glasses.
4	F.	24	M. $\frac{1}{10}$	$\frac{\cdot 0}{xxx}$	Marked diverg. with m. corrected no mov't.	22	....	70	2	....	....	2	....	49	0	....	....	Wears glasses irregularly, for distance only. Eyes never troublesome, though she reads and does fine needlework.
5	F.	12	M. $\frac{1}{24}$	$\frac{20}{xx}$	No perceptible movem't.	2–3	....	34	....	1°	38	0	....	11	1	Less than 1°	16	School girl. Eyes strong. Does not wear glasses.
6	F.	37	Hm. $\frac{1}{36}$	$\frac{20}{xx}$	No perceptible movem't.	0	....	41	2	....	21	0 Less than	....	13	....	....	10	Teaches school. Has worn glasses to correct Hm. for three years.
7	M.	21	E.	$\frac{20}{xx}$	Considerable divergence.	11	....	14[1]	....	....	....	1	....	24	....	....	....	Physician. Reads a great deal. Eyes never troublesome.
8	M.	41	E.	$\frac{20}{xx}$	No perceptible movem't.	3	....	60	....	....	....	0	....	10	....	....	....	Bookkeeper. Wears, in near vision, $+\frac{1}{60}$.
9	F.	29	Hm. $\frac{1}{48}$	$\frac{20}{xx}$?	No perceptible movem't.	0	....	34	1–2	....	....	....	1°	12	....	1	....	School teacher. Reads a great deal. Has never worn glasses.
10	M.	23	E.	$\frac{20}{xx}$	No perceptible movem't.	8	....	34	....	....	....	1	....	16	....	....	....	Bookkeeper. Writes constantly and never has any trouble with eyes.
11	F.	15	E.	$\frac{20}{xx}$	No perceptible movem't.	5	....	34	....	....	....	1	....	10	....	....	....	Attends school, and is a constant reader. Eyes never troublesome.
12	M.	21	E.	$\frac{20}{xx}$	No perceptible movem't.	2	....	27	....	....	....	....	1	16	....	....	....	Med. student. Reads a great deal, and never experiences discomfort from it.

[1] Upon second trial, after acquiring the nack of contracting the internal recti, he was able to overcome at 12″ 55°.

refraction were found to exist the tests were applied, first without, and then with correcting glasses. The vertical diplopia tests were made at 12″, and at 20′; at the former distance the test object employed was a small star with short, vertical bisecting line, held a little below the level of the eyes; and at 20′ a candle-flame, similarly placed. The prism used for producing the diplopia was one of only 7°, which was found quite strong enough, and more convenient for the purpose than those of greater power. As supplementary to the diplopia tests the cover test was applied at 12″, and the capacity of the internal recti muscles to overcome prisms producing lateral displacement was determined in each instance. In examining the state of refraction only the *manifest* hypermetropia was determined, as it was not considered important to ascertain the total amount.

Twelve persons, selected as I have said with especial reference to their freedom from asthenopia, in spite of their eyes being much used in near work, were examined in this manner. The result obtained in each instance is given in the table on the preceding page.

Although the number of eyes which I have examined is not large, it is sufficient for the end in view, since the results obtained show that relative divergence of the visual lines, such as has been regarded as proof of insufficiency of the internal recti muscles, does, in fact, occur very frequently, as an accompaniment of induced vertical diplopia, even in the strongest-eyed persons. A glance at the table will show that this took place, to a greater or less extent, not only in every emmetropic person examined, but that it happened in connection with low grades of manifest hypermetropia, uncorrected by glasses, in three instances in five. Of the five emmetropic persons, with the test object at 12″, one exhibited a divergence indicating an insufficiency of the internal recti muscles of 2°, and the others of 3°, 5°, 8°, and 11° respectively; and even with the object at 20′, three of these showed slight relative divergence. In the hypermetropes, with the test at 12″, an apparent insufficiency of 3° was associated with Hm $\frac{1}{60}$, 2° in one instance, and 6° in the other with Hm $\frac{1}{48}$, and of the two individuals in whom no insufficiency was discovered Hm $\frac{1}{48}$ was present in one and Hm $\frac{1}{36}$ in the other. As might be expected, none of the hypermetropes showed any apparent insufficiency of the interni at 20′, but, on the contrary, one of them showed apparent insufficiency of the externi.

The influence of the state of refraction upon the behaviour of the internal recti muscles, and the way in which neutralizing glasses modify the results of the vertical diplopia tests, are well shown in the table. Thus, while the five hypermetropes show at 12″ an average apparent insufficiency of $2\frac{1}{5}$°, which with correction of the manifest error of refraction is increased to $3\frac{2}{5}$°, the emmetropes show an average of $5\frac{4}{5}$°, and the two myopes of 12°. Furthermore, it will be seen that the 22° of apparent insufficiency which

is associated (in No. 4) with M $\frac{1}{10}$, is reduced to 2° when the test is repeated with neutralizing glasses, and that (in No. 5) an apparent insufficiency of the interni of 2° to 3° is changed to apparent insufficiency of the *externi* of 1° by the correction of M $\frac{1}{24}$.

Another point to which I have alluded, the contradictory character of the results which are obtained in many cases from the different tests for determining the strength of the internal recti muscles, is also well shown. Thus, No. 4, though exhibiting at 12″ (with M $\frac{1}{10}$ uncorrected) an apparent insufficiency of 22°, twice as much as any of the others, was able to overcome, at the same distance and without neutralizing glasses, prisms with bases outwards amounting to 70°, while No. 1, with 3° of insufficiency, overcame but 14°, No. 12, with 2° of insufficiency, but 27°, No. 6, with no insufficiency, but 41°, and No. 9, also with no insufficiency, only 34°, less than half as much. The explanation of this paradoxical result is, that the ability to overcome prisms of high power thus placed does not, in fact, depend upon the strength of the internal recti muscles, but simply upon the individual under examination possessing the "knack" of causing these muscles to contract strongly—a faculty which we often meet with in persons who can look cross-eyed at pleasure.

Evidently, then, upon *this* method of ascertaining the strength of the internal recti muscles but little dependence can be placed, and since it has been shown that, in the strongest-eyed persons, relative divergence of considerable degree frequently accompanies vertical diplopia—even when every precaution is taken to prevent confusion in applying the tests—the question arises, How are we to determine the existence of actual insufficiency of these muscles? Of course, we shall have little difficulty in recognizing the higher grades of insufficiency, those which are not far removed from divergent strabismus, but the difficulty occurs in dealing with the slighter degrees—in deciding, indeed, *where to draw the line between sufficiency and insufficiency.* For myself, I confess I do not know where the line should be drawn, whether at eight or at eleven, or, perhaps, at twelve or fifteen degrees of relative divergence; but of one thing I am convinced—that the tests proposed by Von Graefe, as I have understood them, and as I believe they have usually been interpreted, are calculated to lead to erroneous conclusions regarding the strength of the internal recti muscles; and that to prevent this it is necessary, not only to take into consideration the state of refraction, to be sure that the accommodation is properly regulated, and to be careful that an incentive to binocular fixation does not arise through overlapping of portions of the vertically separated images, but, in addition, to recognize the fact *that relative divergence of the visual lines, even of considerable degree, occurring in connection with vertical diplopia, and after these several precautions have been taken, does not necessarily indicate insufficiency of the internal recti muscles, or, at least, that it is not incompatible with entire freedom from functional disorder.*