# The Phoroptor



De Zeng

Dr. James Thorington

To Dr. James Thorington
with the compliments of
the Author.

# The Phoroptor



*By*

HENRY L. DE ZENG

Author of

"THE MODERN PHOROMETER"

PUBLISHED BY THE AUTHOR

CAMDEN, N. J.

Printed in the United States of America

PRESS OF HARPER PRINTING COMPANY
PHILADELPHIA, U. S. A.

# CONTENTS

# PREFACE

HISTORY is replete with illustrations of the fact that progress in scientific knowledge and the development of improved apparatus go hand in hand, each being to a great extent dependent upon the other. It is therefore not surprising that the constantly increasing realization of the important róle played by the motor muscles of the eye in affecting both our vision and health, has been accompanied by marked development in ophthalmologic instruments for making more thorough muscle tests.

If this book contributes in any degree to a clearer understanding of the importance of testing the ocular muscles and of the possibilities of great good to be accomplished through the systematic making of such tests, the object of the work will have been attained.

## CHAPTER I

# The Evolution of Eye Testing

ALTHOUGH spectacles were invented over six hundred years ago by the Italian d'Armati and have since been worn extensively by every civilized nation, little or no development worthy of mention took place either in the general construction or the method of application of spectacles until the discovery of astigmatism, by Thomas Young, during the early part of the previous generation.

It is well within the recollection of the writer when it was the custom to purchase spectacles much after the fashion of shoes, from retail stores, by trying them on and taking the pair which seemed to fit the best; no eye examinations of any sort then being made or considered necessary. However, with the discovery of astigmatism and the advent of the cylindrical lens for its correction, the importance of eye examinations became at once apparent and the necessity of examining each eye separately was also recognized. Today no one desiring a correct pair of glasses thinks of purchasing them in the old way, but consults one trained in the art, who is prepared to systematically test each eye separately and finally both eyes together, and prescribe lenses to meet all requirements, taking into account any imbalances of the motor muscles as well as errors of refraction which may be present.

It has long been recognized that the muscles which move the eyes in their orbits, known as the extrinsic or motor muscles, should be so interrelated or naturally balanced, that the visual axis of one eye will intersect that of the other eye at the point of fixation and the images of the object observed will form on exactly corresponding points in the retinas of the two eyes. In the absence of such natural muscular balance, binocular single vision could only be maintained through constant effort by the weaker muscles; otherwise the stronger and opposing muscle of any pair would rotate the eye toward itself and in so doing prevent intersection of the visual lines at the point of fixation and simultaneously the formation of the images at corresponding points in the two retinas.

As the fundamental law governing binocular single vision is based upon the physiologic principle of corresponding retinal points, the image of the object in view must of necessity lie in exactly the same relative position upon the retina of each eye. The importance, therefore, of perfect motor muscular balance, otherwise known as orthophoria, is apparent if this fundamental requirement is to obtain without constant nervous and muscular effort.

When the motor muscles are not in balance—a condition known as heterophoria—vision is more or less disturbed and discomfiture frequently experienced, small imbalances often passing unnoticed while the higher degrees may produce double vision, otherwise known as diplopia, or may sometimes produce squint with subsequent amblyopia.

With our present knowledge of the important bearing which the motor muscles have upon comfortable binocular single vision, any tests of the eyes made solely in the interest of correcting errors of the refraction and without regard to the status of the motor muscles, are obviously very incomplete and fall far short of constituting a thorough examination.

Every well-grounded refractionist recognizes the intimate relationship which is known to exist between the intrinsic muscles of accommodation and the extrinsic muscles of convergence; also that stimulation of one gives rise to associate action on the part of the other. In consequence of this co-acting relationship existing between the accommodation and convergence, an otherwise balanced pair of lateral muscles could be thrown completely out of balance by inharmonious ciliary action, while on the other hand, a passive accommodation might, through stimulation of the interni, be induced to become active.

Latent hypermetropia, as is well known, frequently manifests esophoria, when in reality the lateral muscles are in balance; or such a condition of the refraction and consequent action of the accommodation, may likewise conceal true exophoria through the associate stimulation of the interni. On the other hand, these conditions may be reversed and active interni might, as a result of reflex ciliary action, manifest an increase of myopia in a truly myopic eye; myopia in an emmetropic or slightly hyperopic eye; emmetropia in a moderately hyperopic eye or reduced hyperopia in a highly hyperopic eye.

Then again the phorias often cause longitudinal stresses and consequent meridinal corneal depressions and because of such corneal changes, false or pseudo astigmatism will appear. This is particularly true of lateral imbalances of higher degree which materially alter the anatomical rotundity of the cornea along the horizontal meridian of the eye.

Furthermore oblique imbalances may manifest cyclophoria through tortion of the globe and in consequence, no final measurements of the oblique muscles should be made until the status of the recti muscles is definitely determined and any imbalances in them corrected.

In every instance where an imbalance of the motor muscles is found, the error must be corrected if perfect binocular vision is to be had without effort, or diplopia with its train of undesirable consequences is to be avoided.

The importance of testing the muscles as well as the refraction is therefore apparent; also the necessity of suitable equipment for making complete refraction and muscle tests.

## CHAPTER II

# The Motor Muscles

EACH eye is supplied with six extrinsic or motor muscles, a pair for effecting lateral rotations, a pair for the vertical rotations and still another pair for the prevention of tortion or turning of the eye on its antero-posterior axis. The first two pair are known as the recti and the last pair as the obliques.

These muscles are all energized from primary or volitional nerve centers which act only in obedience to the will of the mind. These nerve centers are connected with the muscles in such a manner that the eyes are obliged to move together, it being impossible to voluntarily move one eye without moving the other correspondingly in the same general direction. In looking to the right, (right version) the primary nerve center governing this movement of the eyes, sends down stimulation to the right externus and the left internus; while in looking to the left, (left version) the primary center controlling all such movements of the eyes sends stimulation to the left externus and the right internus. In looking up (super vision), both superior recti are simultaneously energized by the primary center having control of the upward rotation of the eyes; while in looking down (subversion) that center controlling the inferior recti effecting all such movements becomes active. To look in an oblique direction, two or more of these centers act in unison so that the requisite group of muscles necessary in effecting such rotations may be energized simultaneously. When converging, as in reading or looking at any object nearer than infinity, both interni and certain other muscles are stimulated simultaneously by those centers having supervision over the convergence. Hence, all voluntary rotations are binocular.

In addition to the distribution of nerve energy from the primary or volitional centers governing all binocular rotations, the motor muscles receive, when required, a further supply of nerve energy which emanates apparently from secondary or fusion nerve centers. These fusion centers are controlled solely by the fusion faculty of the mind and are wholly outside of any domination by the will of the mind. They function purely in the interest of binocular single vision and have the faculty to move the eyes independently in any direction in order that the visual lines may be constantly co-ordinated to intersect at the point of fixation and the image of the object kept at the macula of each eye. All movements of the eyes therefore which are directed by the fusion faculty are involuntary and are executed solely in the interest of binocular single vision. Were it not for the independent muscular action inspired by the fusion faculty and executed through the agency of the fusion centers, there could be no physiologic compensation for muscular imbalances however great or small.

It is now quite evident that the primary or volitional nerve centers cannot cause movement of one eye without bringing the other eye into similar action and therefore are unable to correct or alter any existing muscular imbalances. It is also evident that the secondary or fusion centers can and do cause movements of one eye without moving the other and thus correct, or tend to correct, existing muscular imbalances.

## CHAPTER III

# The Basis of Muscle Testing

TO return to the fundamental law governing binocular single vision and its fixed physiologic principle of corresponding retinal points, the importance of a state of balance of the motor muscles becomes at once apparent if binocular single vision is to obtain without constant muscular action. As the macula is the posterior pole of the eye, it dominates all ocular rotations and is the region on which the image of the object must fall in each eye coincidently if binocular single vision is to follow. Any deviation of the visual axis of either eye from the point of fixation will, of necessity, displace the image from the macula of the deviating eye and thus destroy binocular single vision, unless sufficient stimulation is given by the fusion centers to the proper muscle or muscles, as the case may be, to bring the visual lines into proper coordination and thereby cause them to intersect at the point of fixation.

In orthophoria, where all motor muscles are in balance, the visual lines will intersect at the distant point of fixation and the image of the object will lie at the central macular region of each eye without any action whatever on the part of either the primary or secondary centers, since the law of corresponding retinal points governing binocular single vision is not then infringed. However, should one of the motor muscles in any pair be weaker than its fellow, the eye would be turned to the side of the stronger muscle and in consequence, the image formed by that eye would no longer fall upon the macular region of that retina. The turning of the eye would produce diplopia and were it not for the constant readiness of the fusion sense to give increased stimulation to the weaker muscle and thereby cause it to pull equally with the stronger or opposing muscle of the pair, binocular single vision would not be restored.

Therefore, as the fusion sense alone dominates every independent action of the extrinsic muscles, a displacement of the image from the macular region would bring about immediate reaction of that muscle or those muscles attached to the opposite side of the globe in an effort to prevent visual disturbance, otherwise known as diplopia. Should the image be displaced to the temporal side of the macula in an exactly horizontal direction, only the internal rectus muscle of that eye would be stimulated to action and the resultant rotation of the cornea inwardly and the macula outwardly would be equal to the outward displacement of the image. Such individual reaction is common with any of the recti muscles so long as the amount of the displacement of the image does not exceed the limitations of the fusion field or of the independent contractile power of the muscle concerned. In other words, so long as the amount of such displacement does not exceed the ability of that particular muscle acting independently to rotate the eye sufficiently to relocate the macula beneath the displaced image and thereby re-establish binocular single vision. However, should the image be displaced beyond the limitations of the fusion field, no muscular reaction would take place and the diplopia thus caused would be insuperable or permanent.

Lying within the visual field of the eye there is a fairly well defined area which is presided over by the fusion faculty and which in consequence is known as the fusion field. It is more or less pear-like in shape with the large end pointing toward the nasal side. Its dimensions are approximately 6 prism diopters displacement in width by about 35 to 40 in length, with the macular region located at the center of its vertical dimension and within about eight prism diopters displacement of the nasal end. Images falling within this field at other than the macular region, cause the eye to rotate in the interest of fusion, while those located outside its confines, have little or no effect upon the fusion sense and in consequence cause no movements of the eye. Hence, should the image be displaced either above or below the macula in a vertical direction to the extent of 5 or 6 prism diopters, or nasalward to the extent of about 10 prism diopters, insuperable diplopia would result, for the image in each instance would then be located beyond the confines of the fusion field and the fusion centers would remain dormant.

Since any of the motor muscles may be individually energized, as already explained, through the agency of the fusion sense, their reactional values may be readily ascertained by placing prisms of known quantity systematically before the eye; for diplopia will not be tolerated unless the degree of displacement of the image by the prism is in excess of the reactional range or independent contractile power of the muscle whose duty it is to correct it, or unless the displacement exceeds the limitation of the fusion field. By harnessing the fusion sense in this fashion, it can be made to reveal the comparative reactional value of each extrinsic muscle; all of which is fully explained in the chapters dealing with the duction tests of these muscles.

In order to obtain the highest degree of stimulation in estimating the reactional values of the various recti muscles, through displacement of the image by means of prisms, the double rotary prism unit will be found highly advantageous as compared with prisms of fixed values. In using the double rotary prism unit, the image never leaves the macula and diplopia does not occur until the amount of displacement of the image exceeds the maximum rotation of the eye. Advantage of the highest retinal stimulation to the maintenance of binocular single vision is obtained in this way. When prisms of fixed value are employed in these tests, diplopia occurs the moment the prism is interposed between the eye and the object, for the image is never at the macula until fusion has taken place and the effect of the prism has been overcome. Each increase in the strength of fixed prisms employed in this way, displaces the image farther away from the macula when first applied and therefore upon a correspondingly less sensitive portion of the fusion field, with reduced reactional tendency. It is therefore obvious that the same fusion effort cannot be obtained by the employment of prisms of fixed value as by the use of the double rotary prism unit. Measurements made therefore with the fixed prisms will usually be somewhat less than those obtained by the use of the double rotary prism unit.

The cause of visual disturbances traceable to non-coordination of the visual axes of the eyes having now been shown to be due to a lack of balance of the muscular system of one eye or of both, and that one or more pairs of muscles in one or in both systems may be involved, the motor muscles must be tested in pairs, one pair at a time, if the exact location of an imbalance is to be determined.

To test the motor muscles in pairs, the test must be made monocularly and the basis therefore of all muscle testing should be established on the same foundation as is the testing of the refraction; namely, that each eye should be tested separately for its individual errors, whether they be of a refractive or muscular character or both. Finally both eyes should be brought into the field, with the correction for each in place in muscle work the same as is done in the final stage of a refraction test and any slight changes then made as may be required or considered desirable for the benefit or comfort of the patient.

In making monocular muscle tests, it should be clearly understood that both eyes are always seeing the same test object and that the eye under test is the one before which the prisms and other testing units, including the Maddox rod, are placed. The other eye is termed the fixing eye, as it never leaves its primary or fixed position with respect to the test object or original point of fixation. In addition to the necessity of having both eyes constantly in the field when making the muscle tests or giving muscle exercises, as explained in subsequent chapters of this book, the visual perception must be sufficient in each eye to enable the patient to discriminate quickly and accurately. The vision therefore should not be less than three-fifths of normal in any instance whether a correction for the refraction is needed or not to bring the vision to this standard.

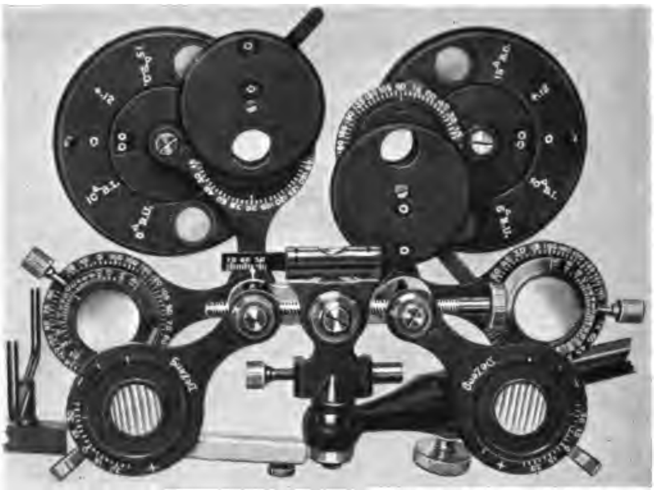
## CHAPTER IV

# The Phoroptor

THE importance of making thorough tests of the motor muscles and of making them monocularly, has been shown in previous chapters to be fully as essential as the making of monocular tests of the refractive media. To meet this necessity, the writer has devised the Phoroptor, which is here briefly described. The instrument contains all of the essentials for making both of these tests in this way, also for giving muscle exercises.

A complete description of the Phoroptor can best be given in terms of its application, and the succeeding chapters should be closely read if a full comprehension of the construction and functioning of the instrument is to be acquired. The suggestions here offered for making the different tests with the Phoroptor will show that the instrument provides exact and complete means for determining the status of the refraction and of the motor muscles, also for strengthening any one or more of the muscles when that is necessary and possible, through a system of gymnastics.

The Phoroptor is binocular in construction and carries on each side five fundamental elements with the necessary supplemental equipment including a near point card holder.



The Phoroptor.
Fig. 1.

The five elements are, (1) the graduated Maddox multiple white rod unit; (2) the universal double rotary, or mobile prism unit; (3) the cylindrical lens unit; (4) the fixed displacing prisms, and (5) the spherical lens unit. These five elements are mounted from front to back in the order named and are fully described in subsequent chapters.

The Phoroptor proper is supported in adjustable fashion upon a horizontal arm projecting from a wall bracket, a floor stand or a chair fixture. Each of these fixtures for carrying the Phoroptor has both coarse and fine adjustments for bringing the instrument into proper alignment with both the patient and the test objects.

The body structure of the instrument consists chiefly of two rearwardly extending arms supported by a pair of adjustable slides, each arm carrying a full complement of the five fundamental elements already mentioned for making complete monocular tests of both the refraction and the motor muscles. A lateral screw adjustment is provided for the slides, also a graduated millimeter scale, and by their use the separation of the two complete aggregations of testing units may be altered to conform with the interpupillary dimensions of the observer. A spirit level is mounted at the center of the instrument for obtaining a true horizontal setting, which is essential in securing an accurate axis for a correcting cylinder, a true base for a correcting prism or an exact axis for a Maddox rod.

Mounted back of the rear shields of the spherical lens batteries are a pair of eye cups, which insure correct positioning of the eyes of the observer with respect to the sight openings in the Phoroptor. These eye cups aid materially in securing accurate results in both the refraction and muscle tests. They also offer some support for the head, thereby reducing the fatigue accompanying eye examinations and the consequent tendency to move the head out of the primary position.

Another auxiliary which is of great utility in muscle testing, is a red color filter which may be placed in operative position before either eye and which furnishes an easy and positive differentiation between the images as viewed by the two eyes.

All of the units embraced in the Phoroptor are adjustably mounted and may therefore be brought into operative alignment individually or in any desired combination. Positive and exact stops are arranged for giving perfect optical alignment to all adjustable elements when placed in operative position before the sight openings.

## CHAPTER V

# The Maddox Rod Units

THE Maddox multiple glass rod, which is the essential part of the graduated Maddox Multiple Rod unit, comprises a lens plano on one side and multi-corrugated on the other. This lens, in effect, is similar to a number of very strong plano convex cylinder lenses placed side by side with their axes parallel. The axis of the Maddox multiple rod is therefore coincident with the direction of its corrugations and light in passing through it is distributed at right angles with its axis. Therefore, if the corrugations or axis were in a vertical position (Fig. 2) a distant spot of light viewed through the rod would be changed in appearance to a horizontal streak of light of the same width as the diameter of the spot, and conversely, if the corrugations or axis were horizontal (Fig. 3), the streak would appear in a vertical position.

The corrugated glass disc or rod proper is mounted in a circular plate having a handle and two indicators. This plate is adjustably supported by a holder which has a degree scale on its upper section and by the combined use of this scale and the indicators on the plate, the amount of rotation which may be given to the rod by the handle will be denoted in degrees of arc. The nasal and the temporal

Maddox Multiple Rods with Axes Vertical.

**Fig. 2.**

quadrants of the scale carry the minus and plus characters respectively for the classification of imbalances of the oblique muscles.

If, in looking at a point of light through the rod with axis vertical, the streak of light thus produced should appear other than horizontal, it could be corrected as to position by a partial rotation of the rod in its holder, the amount of such rotation being registered upon the degree scale in the upper section of the holder. For example, should the indicator stand at the 15 degree graduation in the nasal

Maddox Multiple Rods with Axes Horizontal
Fig. 3.

quadrant of the scale, it would indicate fifteen degrees of minus cyclophoria. Conversely should the indicator show fifteen degrees on the temporal side of zero, a corresponding amount of plus cyclophoria would be indicated, all as fully explained in chapters 16 and 17, dealing with tests of the oblique muscles.

All Maddox multiple rods should be accurately ground on both the plano and the corrugated sides. Ground rods are free from prismatic effects, distortions and other errors which are necessarily present in pressed or blown rods. Researches recently carried out by leading authorities have shown beyond question that blown or pressed Maddox rods are so defective in their function of transforming a point of light into a clearly defined and reliably located streak, that they are wholly unfitted for use in muscle work. Maddox rods which are not ground on both surfaces should therefore never be used in muscle testing instruments, for it is fully as indefensible to use blown or pressed Maddox rods as it would be to use blown or pressed trial case lenses instead of lenses which are perfectly ground. Fortunately for the public, blown or pressed trial case lenses are never used and the increasing realization of the inaccuracies of blown Maddox rods will soon demand the use of nothing but ground rods in eye testing equipment.

## CHAPTER VI

# The Rotary Prism Units

THE universal double rotary, or mobile, prism units described herein, are similar to the Crete and the Risley prisms and are individually composed of two 7½ diopter prisms mounted back to back in separate cells. The cells have gear teeth or annular racks about their outer peripheries and engage a radial pinion which is located between them. When the prism unit is completely assembled within a circular holder forming the prism case and the radial pinion is turned by an extended milled head, the prisms are caused to rotate inversely with respect to each other about a common center. By reason of this inverse rotation, the bases of the prisms may be so interrelated that any desired prism equivalent ranging from zero to the maximum of 15 prism diopters may be obtained. When the bases of the prisms are diametrically opposed, the unit has no prism value and the indicator will then stand at zero. But when the bases of the prisms are at an angle with each other, prism value then exists and the base of the resultant prism equivalent will be located midway upon the arc of their approach. The position of base of the resultant prism equivalent would therefore always be at the 15 diop-

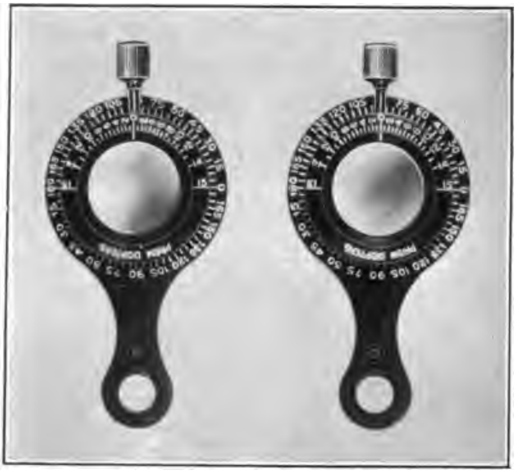
Double Rotary Prisms, Zero Graduations Horizontal.

Fig. 4.

ter graduation of the scale and on that side of zero with which the prism indicator is in register. The more acute the angle between the bases of the prisms becomes, as they approach each other through their inverse rotation when actuated by turning the milled head, the greater the power of the resultant prism equivalent will be, as shown by the position of the movable indicator with respect to the radial prism dioptric scale engraved upon the face of the prism case.

In order that the base of any obtainable prism equivalent may be accurately located in any angular position before the eye, the prism case has an index on either side at the 15 diopter line and is adjustably mounted in a fully graduated support. These indicators on the edge of the case co-acting with the annular degree scale on the mounting, give facility for the universal adaptability of the resultant prism base. With this construction it is evident that any prism equivalent varying in strength from zero to 15 prism diopters may be readily obtained and the base of such equivalent located on any desired meridian.

The prisms function as follows: With zero graduation of the prism scale in horizontal position and the movable indicator set therewith, as shown in Fig. 4, a rotation of the indicator upward to 4 upon the scale would give the equivalent of a 4 diopter prism with base up, while a rotation from zero downward to 4, would give the equivalent of a 4 diopter prism with base down. With zero graduation vertical and indicator set therewith, as shown in Fig. 5, a rotation of the indicator outward to 8 upon the scale would give the equivalent of an 8 diopter prism with base out, while a similar rotation inward from zero,



Double Rotary Prisms, Zero Graduations Vertical.

Fig. 5.

would give the equivalent of an 8 diopter prism with base in. Hence, a rotation of the indicator up or down, when the zero graduation is in a horizontal position, would give the indicated prism equivalent with base located up or down respectively. Similarly, when the zero graduation of the prism scale is vertical, a rotation of the indicator in or out from zero, would give the indicated prism equivalent with base in or out respectively.

The range of the double rotary prism units of the phoroptor is purposely limited to a maximum of 15 prism diopters in order that a more open and readable scale may be had and in consequence, a higher degree of accuracy obtained than would otherwise be possible from the closely graduated scale of prism units having a higher maximum range. This open scale is of especial value where measurements of low degree are required as in making the tests of the vertical muscles.

When prism power greater than 15 diopters is required, as in applying the adduction test, a supplementary fixed prism of 15 diopters may be placed in operative position, base out, in conjunction with the double rotary prism unit. This will extend the prism range of the Phoroptor to a maximum of 30 diopters when base is out. This supplementary 15 diopter fixed prism is carried in one of the shields and is so mounted that its base is always out when it is in operative position before the sight opening.

As the component parts of a double rotary or mobile prism unit require intricate assembly and as they are maintained in functional relationship by a nicely fitted friction ring or retainer, and furthermore, as the prisms are immovably secured within their respective mountings, the taking down and reassembling of one of these complete units would be found exceedingly difficult by one not skilled in the art. Even should the unit be taken down successfully for the purpose of cleaning the inner surfaces of the prisms, the replacement of the geared prism cells in their proper relationship with each other so the prisms would function properly in producing accurate prism equivalents, would likewise be found difficult.

All polished glass surfaces will become cloudy in time and it is therefore important to occasionally clean the inner as well as the outer surfaces of the prisms contained in these mobile units. In order to reach the inner surfaces of the prisms conveniently in the double rotary prism units of the Phoroptor, they comprise a two-part prism cell in one of the mountings in each prism unit which permits the removal of one of the prisms by raising the two retaining screws and taking out the prism fixed in its cell. The screws are placed out of alignment, thereby preventing the improper return of the prism to the unit. This novel feature in construction constitutes quite an important advance, as the heretofore only inaccessible parts of these prism units may now be easily reached and the prisms cleaned without danger of disturbing the assembly or impairing the accuracy of their optical performance.

## CHAPTER VII

# The Fixed Prisms

IN order to extend the range of the double rotary or mobile prism units of the Phoroptor when prism value base out is employed, as explained in chapter 6, a supplementary fixed prism of 15 diopters value is carried in one of the shields of the spherical lens attachment on either side of the instrument. These prisms are so mounted that when placed in operative position before the sight openings their bases are always out, that being the only position of prism base wherein the 15 diopter range of the double rotary prism unit of the Phoroptor might be found inadequate. These supplementary prisms when used in conjunction with the double rotary prism units, will therefore extend their range when base is out, to 30 prism diopters. It is quite evident that the use of these fixed prisms would be confined entirely to the testing of the internal recti muscles, wherein a range of more than 15 diopters of prism value with base out is often required.

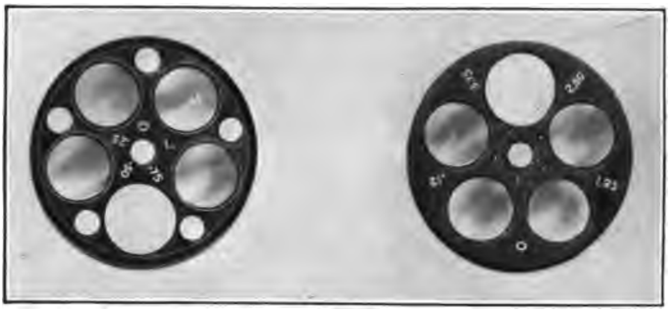
These spherical lens shields also carry other fixed prisms; a pair of 6 diopters and another pair of 10 diopters strength, both pair being used as displacing prisms when making the monocular muscle tests. See Fig. 11 in chapter 9.

All of these prisms are mounted in fixed positions within the shields or carriers and consequently when placed in position for use before the sight openings, their bases are always in a pre-determined or fixed position. The bases of the 15 diopter supplementary prisms are always out or toward the temporal side, the bases of the 6 diopter displacing prisms are always up and the bases of the 10 diopter displacing prisms are always in or towards the nasal side. The functions of these fixed prisms are fully set forth in the following chapters on muscle testing.

## CHAPTER VIII

# The Cylindrical Lens Units

THE cylindrical lens units of the Phoroptor carry minus cylinders only, the cylinders in each unit being contained in two small and conveniently operated dials located on either side of the instrument. The for-



Front Cylinder Dial.
Fig. 6.

Rear Cylinder Dial.
Fig. 7.

ward dial of each unit carries a minus .25, .50, .75, and 1.00 diopter cylinder, also an open sight hole, as shown in Fig. 6. The second or rear dial of each unit carries a minus 1.25, 2.50, 3.75, and 0.12 diopter cylinder in addition to an open sight hole, as shown in Fig. 7. This arrangement places the strongest lenses nearest to the eye under test and the weakest and most frequently used lenses nearest to the operator.

By using the lenses in the two dials either singly or in combination, any minus cylindrical lens value ranging from 0 to 1.25 in subdivisions of eighths and from 0 to 4.75 inclusive in quarters may be obtained on either side of the instrument, thus providing a range of cylindrical lens values sufficient to meet practically every requirement.

All the cylindrical lenses are accurately mounted with their axes radial, which arrangement insures exactly the same position of axis for each lens when it is placed in operative position before the sight opening. To provide for accurate positioning of each lens before the sight opening and to insure a smooth rotation of the dials in which they are mounted, stop springs of precise construction with internal locking members are employed.

The setting of the axis of any of the cylinders at the desired position before the eye is accomplished by swinging the entire unit about the sight opening as a pivotal point, an index on the unit registering with a degree scale impressed upon the supporting mechanism. A handle is attached to each unit by which it may be easily adjusted to give the cylinder lens axis required (Fig. 8). A smoothly working friction attachment holds the unit at any

Cylinder Axis Adjustment, with Scale.

Fig. 8.

desired position of axis setting while the dials carrying the lenses are rotated to obtain the desired cylindrical lens value. The handle used for swinging the unit about the sight opening for changing the axis, forms a convenient rest for the hand while the dials are being rotated with the fingers. This construction permits of easy and rapid changes in either cylinder value or cylinder axis, with but slight movement of the fingers or arm of the operator.

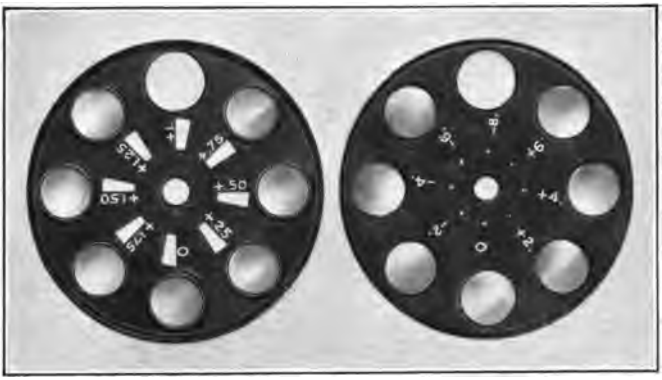
As already stated, only negative cylindrical lenses are included in the make-up of the Phoroptor and while they supply every facility for the measurement of astigmatism, they also contribute greatly to the simplicity of operation and compactness of the instrument.

CHAPTER IX

# The Spherical Lens Units

THE spherical lens units of the Phoroptor each consist of two complete dials of lenses with seven lenses and an open sight hole in each dial and of auxiliary or supplemental lenses mounted in a front and a back shield. The first dial on either side carries a plus 0.25, 0.50, 0.75, 1.00, 1.25, 1.50 and 1.75 diopter sphere and has an open sight hole, as shown in Fig. 9. The second dial on either side carries a plus 2.00, 4.00, 6.00 and a minus 2.00, 4.00, 6.00 and 8.00 diopter sphere and has an open sight hole, as shown in Fig. 10. The second dial being mounted to the rear, places all of the lenses of higher power nearest to the observer, which arrangement guards against any errors which otherwise might arise because of undue separation of these strong lenses from the eyes under test.

The spherical lens units carry no minus spheres of low power but by a simple procedure they may be readily obtained. Through this arrangement the instrument is not encumbered with an extra and unnecessary complement of these low power lenses. To obtain the minus spherical lens values of less than 2.00 diopters, it is only necessary to place in operative position before the sight opening, a minus 2.00 diopter sphere together with the re-




First Spherical Dial
Fig. 9.

Second Spherical Dial.
Fig. 10.

quired plus spheres of such lower power as will give the desired negative equivalents. For example, should both the front and the back dials be rotated upward one position from zero, the minus 2.00 in the back dial and the plus 1.75 in the front dial would give the equivalent of minus 0.25. By a further backward rotation of the first dial only, the plus

1.50, 1.25, 1.00 etc. would be placed consecutively in operative position with the minus 2.00 of the back dial and in consequence, the resultant negative equivalents would be correspondingly increased in power. In this manner the minus spherical equivalents ranging from .25 up to 1.75 diopters may be readily obtained in quarters. To obtain negative spherical equivalents between 2.00 and 4.00 in quarters consecutively, the minus 4.00 in the back dial is next placed in operative position and the front dial carrying the low power plus spheres is again rotated backwards from 1.75 to zero, the same as in the first instance. This procedure will carry the range upwards to 4.00, while the employment of the minus 6.00, minus 8.00 and minus 10.00 auxiliary spheres consecutively or together in this way, will extend the minus range of the instrument to 18.00 inclusive, in subdivisions of quarters.

One of the shields of each unit carries a plus 0.12 diopter sphere, which may be placed in operative position in combination with any of the other spherical lenses, thus making it possible to obtain one-eighth diopter subdivisions throughout the entire range of both the plus and the minus spheres. See Fig. 11.

Each back shield facing the patient carries a plus 8 diopter sphere which may be used to supplement the plus lenses in the forward dials thereby extending the range of the plus spheres to 15.75 inclusive. These same shields also carry the minus 10 diopter sphere previously referred to. See Fig. 12.


Front Shield.
Fig. 11.

Back Shield.
Fig. 12.

A shield on either side has a blank space which may be used as a blinder for excluding either eye from the test and in addition, a red glass color filter, the use of which is described in the chapters dealing with the muscle tests.

The spherical lens dials are constructed with knurled edges to facilitate rotation. The front and back shields are rotated by grasping the small cones which project from their faces near the outer periphery. Both the dials and the shields are provided with three point positive spring stops which insure correct inter-alignment of the dials and positive positioning of the lenses before the sight openings.



## THE NEAR POINT ATTACHMENT

The near point card holder is detachably connected with the Phoroptor and consists of a square tube with a sliding support for holding the test card. The tube is graduated and the fingers which grasp the card are pivotly mounted on the slide. The test card may therefore be moved back and forth or reversed; one side having the acuity and the other the muscle test.

CHAPTER X

# Application of the Phoroptor

SEAT the observer comfortably in direct alignment with the distance test types and adjust the Phoroptor by means of the long P. D. screw, so the space between the centers of the sight openings will conform with the interpupillary measurements of the observer, also make sure the spirit level indicates horizontal balance. Note that the head is in the primary position and the eyes well within the eye cups before beginning the examination. Remove the Maddox rods and the double rotary prism units from operative position by swinging them outwardly and then down out of the way, as they will not be required when testing the refraction.

Employ the customary letter test types, which, together with the astigmatic chart, should be well illuminated. In the writer's opinion the best form of astigmatic chart is one having three normal radiating lines to each 15 degree subdivision of the circle, with large degree numbers at the end of each. The large numbers enable the observer to locate the lines which appear to be the clearest when all are quite indistinct. Wallace's astigmatic chart is ideal in that it meets these requirements exactly and concerning which mention is made in chapter XI. Astigmatic test charts should always be in direct projection of the normal visual line. If either one of the two test charts must be located out of direct alignment, let it be by all means the letter chart, since an angular view of the astigmatic chart must of necessity favor the line or lines lying most nearly in the direction of the inclination.

Chapters 8 and 9, which deal with the cylindrical and the spherical lens units respectively, contain detailed descriptions of the lenses contained therein and of the procedure necessary to obtain any required cylindrical or spherical powers or combinations of the two.

When testing or exercising the muscles, employ the dark room lantern or some other suitable luminous spot of light as the test object. It should be located 5 or 6 meters distant and in direct vertical and horizontal alignment with the Phoroptor. Should the position of the phoroptor be altered to any appreciable extent to meet the requirements of different observers, the position of the test object should then be adjusted accordingly, for the accuracy of a muscle test depends largely upon the maintenance of a correct relationship be-

Dark Room Lantern.

Fig. 13.

tween the test object and the instrument employed in making the tests.

## Dark Room Lantern.

The dark room lantern devised by the writer for use with the Phoroptor when testing or exercising the muscles, (Fig. 13) contains Ziegler's Greek cross, Thorington's iris diaphragm and a white translucent disc mounted on an asbestos tube having ventilated end caps. A round, fully frosted 25 watt tungsten lamp is mounted within the tube and when the diaphragm is adjusted to an opening of 10 m/m or less, only a round spot of tempered white light is visible, the size of the spot being indicated by the reading shown on the graduated scale of the lantern. When the diaphragm is opened to its full extent the Greek cross only is seen.

The lantern is adjustably mounted on a light floor stand; is portable and has cord conductors with socket tap for making electrical connection.

## CHAPTER XI

# The Objective Method

AS an objective examination of the refraction by means of retinoscopy will usually give definite information as to the character and approximate amount of any errors which may be present in the eye, and as the method, because of its value, has increased greatly in popularity during the last decade, the following suggestions for applying this test by means of the Phoroptor in conjunction with the retinoscope may be found serviceable to those who use the Phoroptor routinely in their general refraction work.

Adjust the Phoroptor to the required interpupillary measurement and to horizontal balance and see that the observer's eyes are within the eye cups. Take up a working position directly in front and at any desired or customary distance from the instrument. A 26 inch working distance (the equivalent of two-thirds of a meter), is preferred by many because of the convenience in reaching the instrument for changes in lens powers without having to leave the working position.

Employ preferably a plain mirror retinoscope, the electric instrument being the more convenient because of its self-contained features. Direct the observer's attention to a distant object closely aligned with the head of the operator and project the light into the opening on the side of the Phoroptor corresponding to the eye to be examined. Should the fundus reflex move with the rotation of the mirror, begin the test by placing routinely before the eye gradually ascending lens value in the plus denomination and continue until reversal of the light movement in the pupil is observed in all meridians. Should the reflex move against the mirror, begin the test with minus lens value and increase it until reversal is likewise obtained in all meridians.

Should any single spherical lens value bring about reversal in all meridians, no astigmatism would be indicated, but should more than one spherical lens value be required to bring about reversal in the two chief or opposite meridians astigmatism would be indicated, and in an amount equal to the difference between the lens values employed. The refractive error and the lens for its correction, can be determined only after deducting a plus spherical value of one and a half diopters to compensate for the working distance of 26 inches, or similarly a one diopter plus sphere for a working distance of 40 inches, or one meter.

For example, should a plus 2.00 diopter sphere reverse the movement of the reflex in the vertical meridian, and a plus 3.00 diopter sphere reverse it in the horizontal meridian, when working at 26 inches, the correction after deducting plus 1.50 would be a plus .50 sphere combined with a plus 1.00 cylinder with axis at 90°.

Again, should a plus 1.00 diopter sphere be required to bring about reversal in the vertical meridian and a plus 2.00 diopter in the horizontal meridian, the correction after deducting plus 1.50 for a 26 inch working distance, would be a minus .50 sphere combined with a plus 1.00 cylinder with axis at 90°.

Again, should a minus 1.00 diopter sphere be required to bring about reversal in the vertical meridian and a plus 2.00 diopter sphere in the horizontal meridian, the correction, after deducting plus 1.50 for the 26 inch working distance, would read -2.50 + 3. axis 90°.

Should the required sphere or spheres be of minus character, then in that instance the final correction would be found by adding a minus spherical lens of dioptric power equivalent to the working distance, which is in effect the same as subtracting a plus sphere of the same value in determining the final correction.

Should the employment of cylindrical lenses be preferred to spheres in the measurement of astigmatism by retinoscopy when employing the Phoroptor, they may be readily obtained through a rotation of the small dials of the cylindrical lens units and placed with axis in any desired meridian through a partial rotation of the units about the sight openings. The power of the cylinders may be readily changed without changing the axis, or vice versa. The manipulation of both the cylindrical and spherical lens units are fully set forth in chapters 8 and 9 respectively, the range of the cylinders being from 0 to 1.25 in one-eighth diopters and from 0 to 4.75 in one-quarter diopters, all being minus in character. The range of the spherical lenses is from zero to 15.75 in the plus and to 18.00 in the minus, with subdivisions of eighths throughout the entire range of each.

The dynamic method of skioscopy may be employed if preferred when using the Phoroptor by adding fixation letters to the retinoscope. For detailed information on retinoscopy the reader is referred to the different text books on the subject.

While the addition of an extra or compensating lens to objective refracting equipment may, if employed correctly, facilitate the making of the final calculation, nevertheless the exact focal length of such a lens is rarely maintained as a constant working distance and in addition, it materially reduces the luminosity of the reflex through both reflection and absorption of the light in its transit both ways through such a lens. The employment of a compensating lens is especially disadvantageous in cases where the pupil is small or the eyeground darkly pigmented, as the reflex from such eyes is always faint even under the most favorable conditions of illumination. It is for these reasons that the use of a compensating lens has fallen into general disfavor and in consequence has been omitted from the Phoroptor.

## CHAPTER XII

# The Subjective Method

SEAT the observer comfortably in direct alignment with the distant test charts and place the Phoroptor in operative position with the observer's eyes comfortably within the eye cups after the instrument has been adjusted to the required interpupillary measurements and to horizontal balance; the P.D. scale and spirit level indicating the correctness of these adjustments.

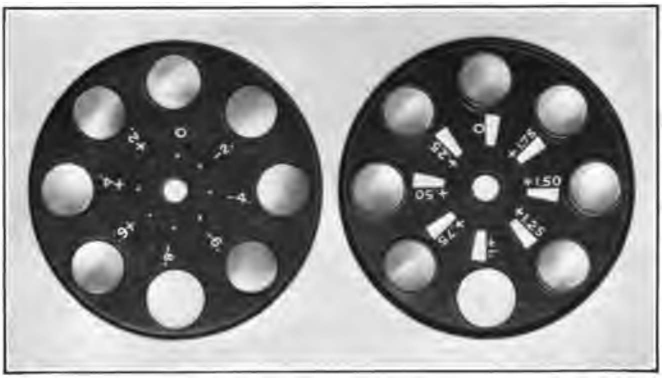
If the right eye is to be tested first place the blinder carried by the shield on the opposite side of the instrument in position to exclude the left eye from the test.

If an objective test of the refraction has previously been made, place the findings in position and proceed to make any changes which may be found necessary in the sphere, the cylinder or the cylinder axis setting.

If no previous test has been made, the spheres and cylinders in the Phoroptor should be employed in the customary manner of using plus and minus spheres with minus cylinders from the test case, and should the fogging system be employed, the minus cylinders will be found of paramount value in this method of testing the refraction.



To apply the fogging system, place as usual before the eye a spherical lens of such strength



Second Spherical Dial.
**Fig. 14.**

First Spherical Dial.
**Fig. 15.**

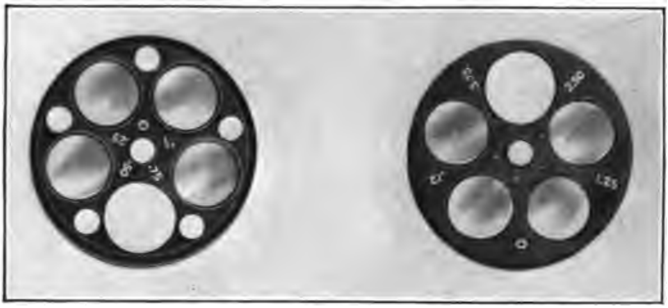
as will blur all of the radiating lines in the astigmatic chart and should a plus 2.00, plus 4.00, or a plus 6.00 sphere be required, it may be obtained by rotating the second dial, (Fig. 14), downward one, two or three points respectively from zero. Should a plus 8.00 diopter sphere be required, it will be found in the rear shield of the spherical lens unit. To reduce plus lens value for instance from 5.75 to 4.00 in steps of one-quarter diopter, the plus 1.75 sphere carried in the end of the lens train in the front dial, (Fig. 15), should be placed in operative position in conjunction with the plus 4.00 of the second dial, (Fig. 14) whereupon plus 5.75 spherical value will be obtained. By a backward rotation of the front dial from plus 1.75 to zero, the total plus power of 5.75 would be reduced in one-quarter diopter steps to plus 4.00. Four diopters would likewise be reduced to plus 2.00 in quarter diopter steps by substituting plus 2.00 for plus 4.00 in the same dial and repeating the operation of backing up the front dial from 1.75 to zero again.

Should a plus 2.50 sphere shade all of the astigmatic lines uniformly in the chart, and a reduction of .50 bring them all into normal relief, there would be no astigmatism and the correcting lens would be plus 2.00 if it likewise gave best obtainable vision on the letter test.

Should a plus 4.00 sphere blur all of the astigmatic lines in the chart and a reduction of same to plus 3.50 bring the vertical lines into almost normal relief with the horizontal lines still indistinct, astigmatism would be indicated and a minus cylinder with axis approximately horizontal would be required to equalize the appearance of the astigmatic dial. In such an instance the axis indicator should be set at approximately 0° or 180° (Fig. 16) and begin-

Cylinder Unit with Axis Horizontal.
Fig. 16.

ning with the low power cylinders contained in the front dial of the cylinder unit (Fig. 17) they should be applied in steadily ascending value until all the lines in the chart were equalized. Should cylinders of higher power than one diopter be required, they could be obtained by employing the second dial, (Fig. 18). A slight reduction then made in the power of the sphere should bring all the radiating lines simultaneously into uniform intensity, if the axis of the cylinder was correct. The correction in such an instance would be written as a plus-minus combination of sphere and cylinder. Should a plus 3.00 sphere and a minus 1.00 cylinder axis 180° be required, the correction



Front Cylinder Dial.
**Fig. 17.**

Rear Cylinder Dial.
**Fig. 18.**

might be so written, or transposed to read plus 2.00 sphere, plus 1.00 cylinder axis 90°. By stopping one-quarter of a diopter short of that spherical lens which would definitely clear the first lines to appear in the astigmatic chart as the original fogging lens is being reduced in power, any overcorrection of the astigmatism through the use of too strong a minus cylinder at opposite axis, would be recognizable. Should the correcting minus cylinder be too strong, the originally blurred lines in that instance would then appear clearer than those in the opposite meridian, while an undercorrection would leave the lines which

Front Shield. Fig. 19.    Back Shield. Fig. 20.

first made their appearance still the most distinct. When all of the radiating lines are uniform in appearance while still slightly fogged to the extent of about one-quarter of a diopter, an exact astigmatic correction is assured, which would not be the case were the accommodation to become active through too great a reduction in the original fogging lens before the astigmatic correction was attempted. There is undoubted advantage to be derived through the use of minus cylinders in connection with the fogging method of eye testing if the spheres are employed as suggested.

While the plus spheres range from 0.25 to 15.75 and are obtainable in quarters as already described, they may be subdivided into eighths by placing the plus 0.12 diopter sphere in position through a partial rotation of the shield carrying this lens. See Fig. 19.

The minus spherical equivalents may likewise be obtained in eighths and quarters to 18.00 but the subdivisions of quarters, halves and single diopters are derived through combining the minus 2.00, 4.00, 6.00 and 8.00 spheres carried in the second dial (Fig. 14) and the minus 10.00 carried in the rear shield (Fig. 20) with the plus spheres carried in the first dial of the spherical lens unit, (Fig. 15).

To obtain a minus 0.25 sphere, the minus 2.00 sphere in the second dial and the plus 1.75 sphere in the first dial are placed simultaneously in alignment at the sight opening. A consecutive increase in the minus is obtained through a consecutive decrease in the plus and this is brought about by a backward rotation of the first dial from 1.75 to zero, when the full effect of the minus 2.00 is obtained. The negative values from 2.25 to 4.00 are obtained by placing the minus 4.00 and the plus 1.75 in operative position simultaneously and then again rotating the front dial backwards to zero; and so on in like fashion until the full range of 18.00 diopters is reached in subdivisions of quarters.

As previously stated, all of the lenses contained in the cylindrical lens units are minus in character and are carried in two rotatable dials, the first dial containing minus 0.25, 0.50, 0.75, 1.00 and an open sight hole, (Fig. 17). The second, or rear dial, contains minus 1.25, 2.50, 3.75, 0.12 and an open sight hole, (Fig. 18) As will be seen, this arrangement gives every minus cylindrical equivalent from zero to 1.25 in subdivisions of eighths, and in quarters to minus 4.75 inclusive. The exact axis readings are plainly visible when the cylinders are in any required position. The focal numbers of the lenses are likewise easily seen.

CHAPTER XIII

# The Coordination Test

**Employing the Double Rotary Prism Units, the Maddox Multiple Rod Units and a Luminous Test Object**

HAVING made a thorough test of the refraction and placed in position before each eye a well centered correction for any

Maddox Rod with Axis Horizontal.
**Fig. 21.**

errors of same which may be present, attention should then be given to the relationship existing between the visual axes of the two eyes, otherwise known as the coordination of the visual lines, since any tendency towards deviation of one, or of both of these lines from exact intersection at the point of observation, or fixation, must be shown in the findings if the examination is to be exhaustive and the proper glasses are to be prescribed. The vision in each eye should not be less than three-fifths of normal in this test.

In order to determine what the tendency of the visual lines may be with respect to the

Fig. 22.

Fig. 23.

Fig. 24.

point of fixation by means of the coordination test at either the far or the near point, a Maddox rod and point of light should be employed in the following manner.

To test the lateral tendency of the visual lines when fixing at distance, place a Maddox rod before either the right or the left eye with axis horizontal, (Fig. 21) and direct the observer's attention to a point of light two or three millimeters in diameter located in direct vertical and horizontal alignment with the Phoroptor five to six meters distant in the dark room. With the Maddox rod before the right eye, the vertical streak as seen by that eye will cut the point of light as seen by the left eye (Fig. 22) if there is no manifest disturbance of lateral coordination. However, should the streak of light appear to the observer's right hand and the point of light to his left hand (Fig. 23) the visual lines would in that instance be crossing somewhere between the observer and the point of light, or point of fixation, and an inward turning of either the right or the left eye, or both, as the case might be, would be indicated. Such an inward turning of either one, or both eyes would denote an imbalance in one or both pair of the lateral recti, which imbalance would be termed esophoria. Should the positions of the streak and spot of light be reversed, the streak appearing to the observer's left hand and the spot to his right hand (Fig. 24) the visual lines would in that instance be tending to cross beyond the point of light, or point of fixation and an outward turning of either the right or the left eye, or both, as the case might be, would be indicated. Such an outward turning would denote an imbalance in either one, or in both pairs of the lateral recti, known as exophoria.

The amount of any lateral deviation of the visual lines which might be uncovered in this way, could be determined by placing a double rotary prism unit in operative position with zero graduation vertical (Fig. 25) and then

Double Rotary Prism, Zero Graduation Vertical.
**Fig. 25.**

employing prism power with base out for esophoria or in for exophoria in such amount as might be required to cause the streak of light to cut the point of light. The double rotary prism unit on either side of the instrument may be employed in making these measurements but the one on the side with the Maddox rod is preferred, as it will then be in front of the eye seeing the streak of light, or the false image.

To test the coordination of the visual lines vertically, the Maddox rod should be set with axis vertical (Fig. 26) and if placed before the right eye a horizontal streak of light should be seen by that eye and a distant point of light by the left eye. Should the streak cut the

Maddox Rod, Axis Vertical.

Fig. 26.

point (Fig. 27) there would be no manifest disturbance of vertical coordination, but should the streak appear below the point (Fig. 28) the visual line of the right eye would then be tending upward or above the true horizontal plane of the point of light, or else the visual line of the left eye would be tending downward below this plane and in either case an imbalance in one, or in both pairs of the vertical recti would be indicated. Such an imbalance is customarily expressed as hyperphoria. However, should the streak of light appear above the point of light in this test (Fig. 29) the imbalance de-

Fig. 27.

noted thereby is usually expressed as cataphoria. The amount of manifest error in the coordination of the visual lines in the vertical plane may be determined by placing a double rotary prism unit in position preferably be-

Fig. 28.

Fig. 29.

hind the Maddox rod, as before, but with its zero graduation horizontal (Fig. 30) and then employing prism power base down in hyperphoria, or up in cataphoria, as may be required to cause the streak of light to cut the point of light. These tests may likewise be made at the near point and when doing so the reading correction should be in place and the interpupillary adjustment of the instrument reduced about 3 millimeters for an average p. d. A very small spot of light (about 1 m. m.), or a 2 m.m. black dot at the center of a plain square white card should be employed at the reading distance as the test object.



This preliminary test of the fixation, otherwise known as the coordination test, has here-

Double Rotary Prism, Zero Graduation Horizontal.
Fig. 30.

tofore been generally entitled the binocular muscle test but as no test of the motor muscles conducted binocularly in a case of imbalance could reveal the deviating eye or the faulty muscle or muscles involved, the title of binocular muscle test seems both incorrect and misleading. The most that a test of the motor muscles made binocularly can disclose is the presence or absence of balance between the two separate and distinct monocular muscular systems, as indicated by the tendency of the visual lines with respect to the point of fixation. While the coordination test made as described, will usually indicate the state of interbalance of the visual lines, by reason of a reduction in the desire for fusion, due to the minuteness and dissimilar character of the image as received by each eye, nevertheless it rarely if ever unmasks the full error because of the location within the fusion area of the images imprinted upon the two retinas. Having no practical value, the binocular muscle testing feature heretofore a part of practically every phorometer, has been omitted from the Phoroptor.

In determining the causes of non-coordination of the visual lines, monocular tests of the recti muscles should be made at both the far and the near points. Such tests are described in the following chapters.

## CHAPTER XIV

# Monocular Tests of the Recti Muscles

**Employing the Fixed Displacing Prisms, the Double Rotary Prism Units, and a Luminous Test Object.**

MONOCULAR tests of the recti muscles are made in a dark room with the aid of a luminous test object located five or six meters distant and in direct vertical and horizontal alignment with the Phoroptor when adjusted to operative position.

One of the best test objects for this type of muscle testing is the Greek cross contained in the dark room lantern shown in Fig. 13.

Should the observer be ametropic an accurate and well centered correction for the error should be in place while making these tests, and particularly so, should the error be hyperopic in character. The vision in each eye when corrected should equal or exceed three-fifths of normal for any muscle test.

To test the lateral balance of the right eye, rotate into operative position before that eye the fixed six diopter displacing prism in the shield of the spherical lens unit (Fig. 19.)

This prism is so mounted that it will come into place at the sight opening with its base up and will accordingly displace the retinal image upward beyond the limit of the fusion field, thus producing insuperable vertical diplopia. Should the lower or false object then seen by the right eye lie directly beneath, or in the same vertical plane with the upper, or true object seen by the left eye (Fig. 31) there

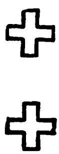


Fig. 31.

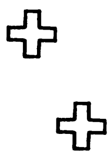


Fig. 32.

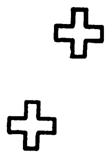


Fig. 33.

would be no manifest lateral imbalance of the right eye. If, however, the lower object should appear to the right of the upper object (Fig. 32) right esophoria would be manifest, while if to the left, (Fig. 33) right exophoria would be manifest and in either instance the amount of the imbalance could be correctly measured by placing a double rotary prism unit in operative position before the eye under test with zero graduation vertical (Fig. 34) and rotating the indicator outward or inward respectively from zero to that point on the prism scale wherein both objects would appear to lie in the same vertical plane and then taking the reading accordingly. All required rotations of the indicator of the rotary prism unit outward from zero measure esophoria, while those inward from zero measure exophoria of the eye under test.

Double Rotary Prism, Zero Graduation Vertical.
**Fig. 34.**

The lateral balance of the left eye should be tested in like manner and in each instance when the tests have been completed the findings recorded for reference.

To test the vertical balance of the right eye rotate into operative position before that eye the fixed ten diopter displacing prism also carried by the shield of the spherical lens unit (Fig. 19). This prism is likewise mounted in such manner that it will come into position at the sight opening with base in and will therefore displace the image on the retina inwardly



Fig. 35.

beyond the fusion field and thereby produce insuperable horizontal diplopia. Should the right hand, or false object seen by the right eye, lie in the same horizontal plane with the left hand or true object seen by the left eye

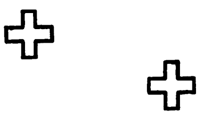


Fig. 36.

Fig. 37.

(Fig. 35) there would be no manifest vertical imbalance of the right eye. If, however, the object to the observer's right should lie below the horizontal plane of the object to the left (Fig. 36) right hyperphoria would be manifest, while if above (Fig. 37) right cataphoria would be manifest and in either instance the amount of the imbalance could be correctly measured by placing a double rotary prism unit in operative position before the right eye with zero graduation horizontal (Fig. 38) and rotating the indicator downwards or upwards respectively, from zero to that point on the prism scale wherein both objects would appear

Double Rotary Prism, Zero Graduation Horizontal.
Fig. 38.

to lie in the same horizontal plane and then taking the reading accordingly.

All required rotations of the indicator of the rotary prism downward when zero is horizontal, measure hyperphoria, while those upward, measure cataphoria of the eye behind the prism, it being the one under test.

The vertical balance of the left eye should be tested in like manner and the findings in each instance recorded for reference.

The red glass color filters contained in the Phoroptor may be employed advantageously in making any of these tests. By placing one of the filters before the eye under test the false object seen by that eye is readily identified because of its red appearance.

In muscle testing as well as in muscle exercising no prisms should be placed before the fixing eye, although as previously stated, it should have a well centered correction for any refractive errors that might be present.

If, upon the completion of a monocular muscle test, made in this way, at either the far or the near point, an imbalance should be shown to exist in one or in both eyes, the independent contractile power of each muscle involved in the imbalance should be individually tested. This may be done by employing the "Duction Tests of the Recti Muscles" described in the next chapter.

CHAPTER XV

# Duction Tests of the Recti Muscles

**Employing the Double Rotary Prism Units and a Luminous Test Object.**

THE duction tests of the recti muscles are based on Savage's physiologic principle, which teaches that when a prism is placed before the eye with base located accurately in, out, up or down, only that rectus muscle lying beneath the apex of the prism is stimulated to action, all the other recti muscles of the two eyes remaining passive in so far as the effect of the prism is concerned.

By utilizing this fundamental principle, as explained in the earlier chapters of this book, the independent contractile power, or range of disassociated action of each rectus muscle may be accurately measured and its value relatively compared, whereupon the origin of an imbalance may be determined.

This muscle test, like the monocular test of the recti muscles, should be conducted in a dark room with the aid of a luminous test object, preferably the Greek cross, located five or six meters distant and in direct vertical and horizontal alignment with the Phoroptor.

An accurate and well centered correction for the observer's ametropia, if any, should be in place during these tests and the vision in each eye when corrected should not be less than three-fifths of normal if reliable data are to be obtained.

Double Rotary Prism, Zero Graduation Vertical.
Fig. 39.

To test the right adduction, or independent contractile power of the internal rectus muscle of the right eye, variable prism value with base out, or towards the temporal side, should be employed. A double rotary prism unit should therefore be placed before the right eye with zero graduation vertical (Fig. 39) and the indicator rotated slowly outward from zero until the object is caused to double in appearance in the horizontal plane, at which point a reading from the prism scale should be taken. Since the range of the double rotary prism units of the Phoroptor is but 15 prism diopters and as the adduction requirements are usually in excess of that figure, it doubtless will be necessary to place in operative position the supplementary 15 diopter fixed prism located in the shield of the spherical lens unit. This prism is so mounted that its base is always out when in operative position at the sight opening and when used in conjunction with the double rotary prism unit, a continuous range of from zero to 30 prism diopters base out is available, with the added advantage of open scale readings for the full prism range.

The adduction test should be repeated several times in order to obtain the highest prism value with base out which can be accepted without diplopia, or double vision. The prism value thus obtained will indicate the right adduction and should be so recorded.

To determine the right abduction, or independent contractile power of the external rectus muscle of the right eye, variable prism value with base in, or towards the nasal side, should be employed. The double rotary prism unit should therefore remain in the same relative position as before, with zero graduation vertical, but the indicator in this instance should be rotated in the opposite direction, or inward from zero. This inward rotation of the indicator should be continued until the object appears to double in the horizontal meridian as before, when a reading from the prism scale should be taken. Like the former, this test should be repeated several times or until the highest prism value with base in which can be accepted without diplopia is obtained. This will indicate the right abduction and should be so recorded.

The 15 diopter supplementary prisms are for use in the adduction test only.

The adduction and abduction are rated normally at about 3 to 1 or 24 to 8 prism diopters respectively. This however may vary considerably in different instances but the three-to-one rule usually applies.

To test the right superduction, or independent contractile power of the superior rectus muscle of the right eye, variable prism value with base down should be employed. The double rotary prism unit should therefore be placed before this eye with zero graduation horizontal (Fig. 40) and the prism indicator rotated slowly downward from zero until the object appears to double in the vertical plane. The highest prism value with base down which can be accepted without diplopia will indicate

Double Rotary Prism, Zero Graduation Horizontal.
Fig. 40.

the right superduction and when found should be so recorded. This will usually equal 2 or 3 prism diopters but may fall as low as zero, or run as high as 4 or 5 in some instances. This test should be repeated several times before the result obtained is accepted as final. Care should be exercised when making this test as it is most sensitive, due to the limited range of independent action of the vertical muscles.

To determine the right subduction, or independent contractile power of the inferior rectus muscle of the right eye, variable prism value with base up should be employed. The double rotary prism unit should therefore remain in the same relative position as before, with zero graduation horizontal, but the indicator in this instance should be rotated slowly in the reverse direction, or upwards from zero until the object appears to double in the vertical plane. The highest prism value with base up which can be accepted without diplopia will indicate the right subduction and should be so recorded. This, like the former, will usually equal two or three prism diopters but may also fall as low as zero or run as high as 4 or 5 in some instances. This test also should be repeated several times, as it is likewise sensitive and must be carefully conducted if an accurate estimate of the subduction is to be obtained.

When the tests of the four recti muscles of the right eye have been completed in the manner described, similar tests should be made of each of the four recti muscles of the left eye and the results of the tests accurately recorded.

After testing each rectus muscle of each eye separately in this manner, a comparison of the results obtained should indicate the relative tendency of the visual axes and in the event of an imbalance, which muscle or muscles of either eye, or both eyes, as the case may be, are lacking in tone. Muscle exercise, prism

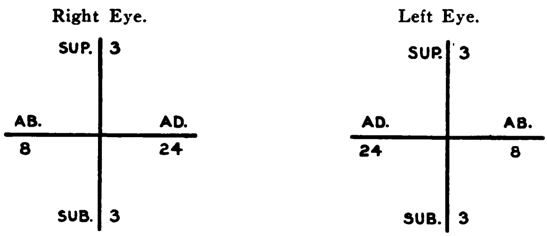



Fig. 41.

lenses or operative procedure may then be prescribed with definite knowledge of the requirements in practically every instance.

Fig. 41 illustrates a case of perfect muscular balance, otherwise known as Orthophoria.

To illustrate the application of this test, take for example a case of lateral imbalance showing the following muscle findings expressed in prism dioptric values. Right adduction of 24 with an abduction of 8 (Fig. 42) left adduction of 18 with an abduction of 8 (Fig. 43). A comparison of these figures will indicate a left exophoria arising from a manifestly weak left internus.

Likewise in cases of esophoria, hyperphoria or cataphoria, definite muscle measurements made independently in this manner will usually indicate which muscle or muscles, as

Right Eye.

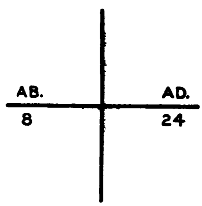



Fig. 42.

Left Eye.

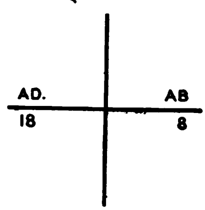



Fig. 43.

the case may be, are relatively too strong or too weak and consequently which of the recti are involved in the imbalance.

## Oblique Monocular Imbalances and the Universal Double Rotary Prism Units

Oblique monocular imbalances often manifesting false cyclophoria, being more readily measured and corrected by the use of a single

Double Rotary Prisms, Base Lines Oblique.

Fig. 44.

prism with base located obliquely than by the employment of two separate prisms for the same eye with bases placed 90 degrees apart, the universal double rotary prisms with their adaptability of base to any meridian are most effective in cases of this sort.

The universal prisms also provide ideal means for the simultaneous exercise of either of the lateral with either of the vertical muscles of the same eye in a most exact manner. This, as previously explained, is owing to the improved manner in which these double rotary prism units are mounted, the fully graduated support and rotatable prism case with indicators supplying exact means for locating the base of any derived prism value in any angular position before the eye. See "Exercise of Two Recti Together," Chapter 18.

CHAPTER XVI

# Monocular Test of the Oblique Muscles

**Employing the Maddox Multiple Rod Units, the Fixed Displacing Prisms of 6 Diopters and a Luminous Test Object.**

IMBALANCES of the oblique muscles, giving rise to cyclophoria, are detected by the combined use of two Maddox multiple rods and a six diopter fixed displacing prism in the following manner.

Maddox Rods, Axes Vertical.
Fig. 45.

Darken the room and direct the observer's attention to a spot of light two or three millimeters in diameter, located five or six meters distant and in the same vertical and horizontal planes with the Phoroptor. An accurate and well centered correction for the observer's ametropia, if any, should be in position when making these tests and the vision in each eye when corrected should not be less than three-fifths of normal.

Fig. 46.

Place in operative position before the right eye, the six diopter displacing prism, which, owing to its setting, will come into place base up, (Fig. 19.) Next place both Maddox rods in operative position with the axis of each set vertical (Fig. 45.) The observer should then

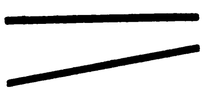


Fig. 47.

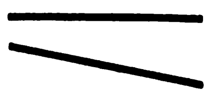


Fig. 48.

see two separate and distinct streaks of light each lying in an approximately horizontal plane, the streak seen by the right eye appearing to lie below the one seen by the left eye. Should the upper streak lie in the horizontal plane and the lower streak be parallel with it

(Fig. 46) there would be no manifest cyclophoria of the right eye. However, should the upper streak seen by the left eye remain horizontal and the lower streak seen by the right eye appear to lie at an angle therewith, there would be cyclophoria of the right eye and should the lower streak dip to the observer's left hand (Fig. 47) right plus cyclophoria would be manifest, whereas right minus

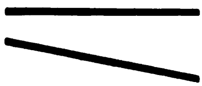


Fig. 49.

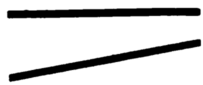


Fig. 50.

cyclophoria would be manifest should it dip to the observer's right hand (Fig. 48.)

With the six diopter displacing prism removed from before the right eye and the one on the other side of the instrument placed in position before the observer's left eye, base up, the streak seen by the left eye would then appear to lie below the one seen by the right eye and should the upper streak be horizontal and the lower one parallel with it (Fig. 46) there would be no manifest cyclophoria of the left eye. If, however, the upper streak should remain horizontal and the lower streak should appear at an angle with it, the left eye would be cyclophoric; left plus cyclophoria being manifest should the lower streak dip to the observer's right hand (Fig. 49) or left minus cyclophoria, should it dip to the observer's left hand (Fig. 50).

The character of the cyclophoria may be readily determined and the amount measured by means of the indicators and graduated scales with which the Maddox rods are provided. This is accomplished by rotating the respective rod to that position which will cause the tilting streak of light to appear horizontal, whereupon the position of the indicator with respect to the temporal or the nasal quadrants of the scale, as the case may be, will characterize the cyclophoria as plus or minus and signify the amount present in degrees of arc.

The red glass color filters contained in the Phoroptor may be employed advantageously in making any of these tests. By placing one of the filters before the eye under test, the false object seen by that eye is readily distinguished from the true object seen by the fixing eye, because of its red appearance.

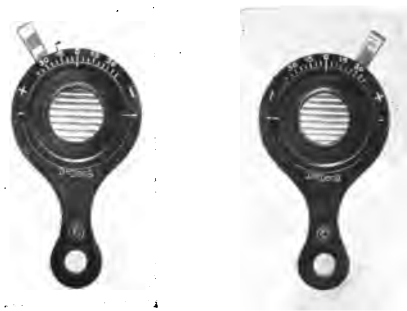
These tests are particularly important in instances where the observer requires a high astigmatic correction with cylinder axis lying in an oblique meridian. See "Ophthalmic Neuro-Myology" by Savage.

## CHAPTER XVII

# Duction Tests of the Oblique Muscles

**Employing the Maddox Multiple Rods and a 10 M/M Luminous Test Object.**

THE range of independent action of the oblique muscles may be measured in a dark room by means of a test known as the cycloduction test.



Maddox Rods, Axes Horizontal.
Fig. 51.

To make this test, place a Maddox multiple white rod in operative position before each eye with the axis of each rod horizontal (Fig. 51) and employ a luminous test object about 10 m/m. in diameter, located five or six meters distant in the dark room and in direct vertical and horizontal alignment with the Phoroptor.

Should the observer be either ametropic or heterophoric, or both, a suitable correction for same should be in place, for any action by the recti is undesirable during the making of these tests. The vision when corrected should not be less than three-fifths of normal for each eye.

The observer should see but one broad verti-

Fig. 52.

Fig. 53.

Fig. 54.

cal band of light (Fig. 52) and to measure the duction range of the superior oblique of the right eye, the rod on the corresponding side of the instrument should be rotated slowly and steadily downward at its nasal end until the band of light begins to break or assumes the appearance somewhat of the letter X (Fig. 53) whereupon the position of the indicator with respect to the inner scale will denote the degree of right minus cycloduction.

Upon returning the rod to its former position for a moment, with axis horizontal and indicator at zero, it may be rotated downward at the temporal end until the vertical band of light breaks in the opposite direction (Fig. 54) whereupon the position of the indicator with respect to the outer scale will denote the duction range of the right inferior oblique, or the degree of right plus cycloduction.

The plus and the minus cycloduction of the left eye may be taken in like manner. The results obtained in each instance should be recorded for comparison. The duction range of the oblique muscles when taken in this way, will average between 5 and 15 degrees of arc although it may fall as low as 2 or 3 in some eyes and rise as high as 25 in others.

The Maddox rods employed in these tests should be white, otherwise the full fusion effort of the oblique muscles will not be obtained and in consequence no reliable data gathered.

Heterophoria of whatever type may be profitably investigated by making a thorough duction test of each extrinsic muscle separately for the origin of an imbalance can usually be determined through a relative comparison of the individual muscle values.

## CHAPTER XVIII

# Exercise of the Recti Muscles

**Employing the Double Rotary Prism Units and a Large Luminous Test Object.**

THE recti muscles may be exercised effectively for the correction of an imbalance through the employment of the double rotary prism units in the following manner.

Should a duction test of the recti muscles made in a case of Exophoria show for example, a right adduction of 24 prism diopters with an abduction of 8, and a left adduction of 18 with an abduction of 8 (Figs. 55 and 56) the imbalance would be manifestly attributable to the inherent weakness of the left internus.

To exercise this weak left internal rectus muscle independently, a double rotary prism unit should be placed before the left eye only, with zero graduation vertical (Fig. 57) and the attention of the observer directed with both eyes to a large luminous test object—preferably the Greek cross—located 5 or 6 meters distant in the dark room.

An alternately increasing and decreasing prism value should then be applied with base opposite the muscle to be exercised. Therefore, in this instance, the prism pinion should be so turned as to cause a slow and steady rotation of the indicator outward from zero to 10 or 12 upon the prism scale, and then be slowly reversed to zero again. This alternate rotation of the indicator outward from zero and back again will cause the muscle to con-

Right Eye.

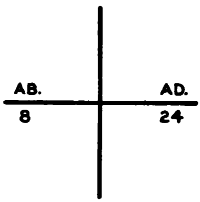



Fig. 55.

Left Eye.

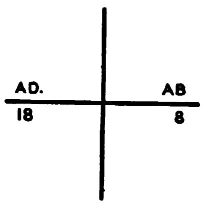



Fig. 56.

tract steadily as prism value is increased and then in turn relax as prism value is decreased, thereby producing a natural and effective exercise, which, as is evident, may be given independently to any rectus muscle of either eye through the correct use of the prism.

If, after exercising a muscle or muscles, as the case may be, in this way four or five minutes a day for several days, a stronger prism can be accepted than at first, the range of exercise may be correspondingly lengthened and the practice continued until permanent balance is obtained.

Rotary Prism, Zero Graduation Vertical.
Fig. 57.

An accurate and well centered correction for refractive errors should be worn by the observer during the period of muscle exercise. The best obtainable vision in each eye should not be less than three-fifths of normal if satisfactory results are to be expected.

## Exercise of Two Recti Together

**Employing the Universal Double Rotary Prism Units and a Large Luminous Test Object**

When a horizontal and a vertical rectus muscle of the same eye are to be exercised together, as for instance, the internal rectus and the inferior rectus for the correction of any

Rotary Prism with Base Line Oblique.
Fig. 58.

hyper-exophoria, a universal double rotary prism unit should be so placed before the heterophoric eye that the base of the variable prism value to be employed in giving the exercise will lie in the upper temporal quadrant. For instance, if, in the original muscle tests, the equivalent of a 6 diopter prism with base located 20 degrees down was required to bring about balance in both the vertical and horizontal meridians, then for the simultaneous exercise of the two recti muscles referred to, variable prism value with base located approximately opposite, or 90 degrees away would be required. Figure 58 shows a double rotary prism unit with prism base line located obliquely.

While most forms of oblique monocular imbalance may be corrected by exercising first one of the weak recti muscles and then the other until balance is restored in both meridians, nevertheless the application of variable prism value with base located obliquely, as described, will be found both expedient and effective when giving exercise in cases of this kind.

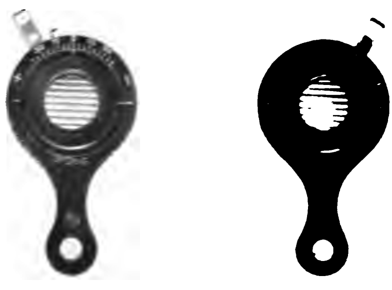
The maximum prism value employed in giving muscle exercise should always be less than that which will produce diplopia. Should the muscle or muscles show improvement following a few periods of exercise, of four or five minutes a day, the treatment may be continued until permanent balance is obtained, otherwise it should be abandoned, as no form of exercise will correct or even assist every case of muscular imbalance.

## CHAPTER XIX

# Exercise of the Oblique Muscles

**Employing the Maddox Multiple Rod Units, and a 10 M/M Luminous Test Object.**

THE oblique muscles may be individually exercised by placing a Maddox graduated multiple white rod before each eye with their axes horizontal (Fig. 59) and employing a luminous test object about 10 m/m in diame-



Maddox Rods, Axes Horizontal.
Fig. 59.

ter, located 5 or 6 meters distant in the dark room and in direct vertical and horizontal alignment with the Phoroptor. This is the same set up of the Phoroptor as described in

chapter 17, on the duction test of the oblique muscles.

Should the observer be ametropic or heterophoric, or both, a suitable correction for same should be in place, as all recti muscles should be at rest while exercising the oblique. And here again, the vision in each eye should not be less than three-fifths of normal if beneficial results are to be expected.

With both Maddox rods in position, as stated, only one broad vertical band of light should be seen.

To exercise the superior oblique of the right eye, the index to the rod on the corresponding side of the instrument should be rotated slowly and steadily inward from zero to a point on the scale one or two degrees short of that point at which the single vertical band of light will break into the form of the letter X, and then returned to zero again. The alternate rotation of the rod through this arc will cause the muscle to contract steadily as the indicator departs from zero and then in turn relax as it approaches zero, thereby producing a natural and effective exercise, which, as is evident, may be applied to the inferior oblique in the same manner by rotating the indicator in the opposite direction, or outward from zero and back again.

The obliques of the left eye may be exercised by employing the rod on the corresponding side of the instrument in like manner.

This form of exercise, like that for the recti muscles, if beneficial after a few trials of four or five minutes a day, should be continued regularly until permanent balance is obtained. Progress in the exercise of the obliques may be determined by taking the cycloduction periodically and comparing the results with the original findings.

When exercising the oblique muscles, white Maddox rods only should be employed as explained in Chapter 17.

CHAPTER XX

# General Definitions of Scientific Terms

BINOCULAR SINGLE VISION. A condition of sight wherein each eye sees the object and both see it as one. This is due to the location of the image at the macula of each eye.

DIPLOPIA. A term denoting double vision. It is brought about through failure of the images in the eyes to fall upon corresponding points in the two retinas.

VISUAL AXIS. The visual axis of the eye is an imaginary line coincident with that central ray of light which suffers the least refraction in passing from the object to the central macula region.

FIXATION POINT. The fixation point is that point towards which the vision is directed and may be located either far or near.

MACULA. The macula is the most sensitive point in the retina and, as such, constitutes the posterior pole of the eye. To obtain distinct vision the image must focus clearly upon the macula.

FUSION FIELD. The fusion field is a limited area within the central region of the retina and surrounds the macula. It is pear-like in shape and is under the direct supervision of the fusion faculty. Images falling within this area at dissimilar points in the two eyes are caused to fuse into one image through stimulation of the motor muscles by the fusion centers.

EMMETROPIA. A term signifying an optically perfect eye, an eye having no errors of refraction and in which parallel rays of light come to a focus on the retina without accommodative effort.

AMETROPIA. A term signifying an optically imperfect eye, an eye having errors of refraction. In such an eye parallel rays of light could not focus upon the retina unless the accommodation assisted or lenses were employed.

HYPERMETROPIA. A term applied to an eye lacking in its refractive power, or to a shallow eye in which parallel rays of light tend to focus back of the retina.

MYOPIA. An eye having an excess of refractive power, or in which the distance from the cornea to the retina is too great. A myopic eye is usually a long eye in which parallel rays of light focus before they reach the retina.

ASTIGMATISM. This term indicates unequal refraction in the different meridians of the eye and is usually due to a lack of rotundity of the cornea. Parallel rays of light entering such an eye focus more quickly in one meridian than in another.

Each of the above general terms referring to errors of refraction of the eye covers a number of subdivisions, all of which may be found in the text books on the subject.

PRESBYOPIA. Old sight, due to a gradual congealing of the crystaline lens matter and frequently spoken of as loss of accommodation. The accommodation is controlled by the intrinsic or ciliary muscle.

ORTHOPHORIA. Orthophoria is a condition of balance of the extrinsic or motor muscles of the eyes in binocular single vision.

HETEROPHORIA. Heterophoria is a term applied to latent imbalances of the extrinsic or motor muscles of the eye. When imbalances of the motor muscles are manifest they are known as tropias, or squints. The phorias admit of binocular single vision while the tropias or squints do not, unless corrected.

ESOPHORIA. An excessive turning in or convergence due to over-developed internal or undeveloped external recti muscles.

EXOPHORIA. Exophoria means a turning outward, being a condition exactly opposite to esophoria and due either to over-development of the external, or lack of development of the internal recti muscles.

HYPERPHORIA. A turning of one eye upward above the horizontal median line, due to an over-developed superior, or an under-developed inferior rectus muscle.

CATAPHORIA. Cataphoria denotes a condition exactly opposite to hyperphoria and signifies a turning down of one eye below the horizontal median line.

CYCLOPHORIA. Cyclophoria means a rotation of the eye on its antero-posterior axis. This condition is usually attributable to an imbalance of the oblique muscles.

ADDUCTION. An inward rotation of the eye in the interest of maintaining binocular single vision.

ABDUCTION. An outward rotation of the eye in the interest of maintaining binocular single vision.

SUPERDUCTION. An upward rotation of the eye in the interest of maintaining binocular single vision.

SUBDUCTION. A downward rotation of the eye in the interest of maintaining binocular single vision.

CYCLODUCTION. A rotation of the eye on its antero-posterior axis in the interest of maintaining parallelism of the vertical planes of the eyes.

PRISM DIOPTER. Prism diopter is a unit of measurement given to prisms and signifies a displacement of the object one centimeter towards the apex when the prism is held a distance of one meter from the object.

RETINOSCOPY also known as Skiascopy. The science of examining the refraction of the eye by directing light into the pupil from a mirror having a sight opening at its center and known as a retinoscope. A movement of the mirror causes a characteristically responsive movement of the fundus reflex appearing in the pupil.

FOGGING SYSTEM. A method of examining

the refraction of the eye with lenses. It consists in the primary employment of spherical lenses of such character and power as will make the eye temporarily myopic in all meridians. This is done to encourage relaxation of the accommodation or to discourage accommodative effort during the period of the examination.

CYCLOPLEGIC. A cycloplegic is a drug used for paralyzing the ciliary muscle of the eye when testing the refraction. It places the accommodation in a state of rest and consequently manifests any latent refractive errors which may be present. It also causes extensive dilation of the pupil.

## CHAPTER XXI

# Scientific Data Frequently Used

IN connection with a study of the refraction and motor muscles of the eye, recourse to certain tabulations of data is frequently advantageous or even necessary. To facilitate such reference work, there is given herewith a very limited collection of the data often needed. Practically all such data is presented in tabulated form.

### FOCAL LENGTHS

The dioptric system of focal designation, is based upon the definition of a one diopter lens, as a lens whose focal length is one meter. The focal length of a two diopter lens is one half meter; of a one-half diopter lens, two meters; etc. Table number one shows the focal lengths in millimeters and in inches of all lenses ranging in power up to 20 diopters.

TABLE 1.

FOCAL LENGTHS.

| Diopters | Millimeters | Inches |
|---|---|---|
| 0.12 | 8000 | 314.93 |
| 0.25 | 4000 | 157.48 |
| 0.50 | 2000 | 78.74 |
| 0.75 | 1333 | 52.50 |
| 1.00 | 1000 | 39.37 |
| 1.25 | 800 | 31.50 |
| 1.50 | 666 | 26.22 |
| 1.75 | 571 | 22.48 |
| 2.00 | 500 | 19.69 |
| 2.50 | 400 | 15.75 |
| 3.00 | 333 | 13.12 |
| 4.00 | 250 | 9.84 |
| 5.00 | 200 | 7.87 |
| 6.00 | 166 | 6.56 |
| 7.00 | 143 | 5.62 |
| 8.00 | 125 | 4.92 |
| 9.00 | 111 | 4.37 |
| 10.00 | 100 | 3.94 |
| 11.00 | 91 | 3.58 |
| 12.00 | 83 | 3.28 |
| 13.00 | 77 | 3.03 |
| 14.00 | 71 | 2.81 |
| 15.00 | 67 | 2.62 |
| 16.00 | 63 | 2.46 |
| 17.00 | 59 | 2.32 |
| 18.00 | 56 | 2.19 |
| 19.00 | 53 | 2.07 |
| 20.00 | 50 | 1.97 |

## PRISM VALUES

A prism diopter denotes a displacement of the image equal to one centimeter at a distance of one meter; two centimeters at a distance of two meters, etc. In conducting the tests and in writing the prescription, the only prism values to be considered are the prism diopter measurements. Occasions frequently arise, however, in which it is desirable to know the actual angle of displacement, or the angle of deviation of the ray of light resulting from the prism action. Table number two on opposite page gives such angular deviations corresponding to all prism diopter values up to 20.

## TABLE 2.

### DEVIATION AND PRISM DIOPTERS.

| Prism Diopters | Angle of Deviation | |
|---|---|---|
| 1 | 0° 34′ | 23″ |
| 2 | 1 8 | 45 |
| 3 | 1 43 | 7 |
| 4 | 2 17 | 29 |
| 5 | 2 51 | 45 |
| 6 | 3 26 | 4 |
| 7 | 4 0 | 14 |
| 8 | 4 34 | 29 |
| 9 | 5 8 | 39 |
| 10 | 5 42 | 39 |
| 11 | 6 16 | 43 |
| 12 | 6 50 | 34 |
| 13 | 7 24 | 22 |
| 14 | 7 58 | 4 |
| 15 | 8 31 | 50 |
| 16 | 9 5 | 24 |
| 17 | 9 38 | 52 |
| 18 | 10 12 | 14 |
| 19 | 10 45 | 30 |
| 20 | 11 18 | 36 |

## DECENTRATION.

It is a well known fact that the decentering of a lens introduces prism value, and within certain limitations, this simple fact may be used in securing prism effects with the ordinary lenses. The amount of decentration in centimeters is equal to the prism power in diopters divided by the spherical power in diopters. Expressing this the other way about, the prism effect in diopters is equal to the spherical power in diopters multiplied by the decentration in centimeters. Table number three on opposite page shows the amount of decentration required to give the various prism effects up to ten prism diopters in lenses ranging in power up to 20 diopters.

## TABLE 3.

### Decentration of Spherical Lenses and Resultant Prismatic Effects

RESULTANT PRISM DIOPTERS

| Lens Power in Diopters | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MILLIMETER DECENTRATIONS. | | | | | | |
| 1 | 10.0 | 20.0 | | | | | | | | |
| 2 | 5.0 | 10.0 | 15.0 | 20.0 | | | | | | |
| 3 | 3.3 | 6.7 | 10.0 | 13.3 | 16.7 | 20.0 | | | | |
| 4 | 2.5 | 5.0 | 7.5 | 10.0 | 12.5 | 15.0 | 17.5 | 20.0 | | |
| 5 | 2.0 | 4.0 | 6.0 | 8.0 | 10.0 | 12.0 | 14.0 | 16.0 | 18.0 | 20.0 |
| 6 | 1.7 | 3.3 | 5.0 | 6.7 | 8.3 | 10.0 | 11.6 | 13.3 | 15.0 | 16.7 |
| 7 | 1.4 | 2.9 | 4.3 | 5.7 | 7.2 | 8.6 | 10.0 | 11.4 | 12.8 | 14.3 |
| 8 | 1.3 | 2.5 | 3.8 | 5.0 | 6.3 | 7.5 | 8.8 | 10.0 | 11.2 | 12.5 |
| 9 | 1.1 | 2.2 | 3.3 | 4.5 | 5.6 | 6.7 | 7.8 | 8.9 | 10.0 | 11.1 |
| 10 | 1.0 | 2.0 | 3.0 | 4.0 | 5.0 | 6.0 | 7.0 | 8.0 | 9.0 | 10.0 |
| 11 | 0.9 | 1.8 | 2.7 | 3.6 | 4.5 | 5.6 | 6.4 | 7.3 | 8.2 | 9.1 |
| 12 | 0.8 | 1.7 | 2.5 | 3.3 | 4.2 | 5.0 | 5.8 | 6.7 | 7.5 | 8.3 |
| 13 | 0.8 | 1.5 | 2.3 | 3.1 | 3.8 | 4.6 | 5.4 | 6.2 | 6.9 | 7.7 |
| 14 | 0.7 | 1.4 | 2.1 | 2.9 | 3.6 | 4.3 | 5.0 | 5.7 | 6.4 | 7.1 |
| 15 | 0.7 | 1.3 | 2.0 | 2.7 | 3.3 | 4.0 | 4.7 | 5.3 | 6.0 | 6.7 |
| 16 | 0.6 | 1.3 | 1.9 | 2.5 | 3.1 | 3.8 | 4.4 | 5.0 | 5.6 | 6.2 |
| 17 | 0.6 | 1.2 | 1.8 | 2.4 | 2.9 | 3.5 | 4.1 | 4.7 | 5.3 | 5.9 |
| 18 | 0.6 | 1.1 | 1.7 | 2.2 | 2.8 | 3.3 | 3.9 | 4.4 | 5.0 | 5.6 |
| 19 | 0.5 | 1.1 | 1.6 | 2.1 | 2.6 | 3.2 | 3.7 | 4.2 | 4.7 | 5.3 |
| 20 | 0.5 | 1 0 | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 |

## TRANSPOSITION

The transposition of a prescription from its original form is frequently desirable in order that a lens having better curves may be obtained. The rule for transposing is very simple. Add together algebraically the sphere and the cylinder powers for the new sphere; then change the sign of the cylinder and change its axis 90 degrees. Transposition is best illustrated by several examples showing different combinations.

The prescription +1.00= +0.50 axis 90
transposes to +1.50= −0.50 axis 180

The prescription +1.00= −0.50 axis 90
transposes to +0.50= +0.50 axis 180

The prescription +0.50= −1.00 axis 90
transposes to −0.50= +1.00 axis 180

The prescription −1.00= −0.50 axis 90
transposes to −1.50= +0.50 axis 180

The prescription −1.00= +0.50 axis 90
transposes to −0.50= −0.50 axis 180

The prescription −1.00= +0.50 axis 15
transposes to −0.50= −0.50 axis 105

This transposition rule is often stated in a different form to avoid any reference to algebraic additions. To transpose a prescription in which either the sphere or the cylinder is plus and the other minus, subtract the less from the greater using the sign (+ or — ) of the greater for the new sphere. Then combine with it a cylinder of the same strength as before, but of opposite sign and opposite axis.

When both sphere and cylinder are plus, they are simply added together with the plus sign for the new sphere and when both are minus, they are likewise added together using the minus sign and in either case, the new cylinder is of the same strength as before but of opposite sign and axis.

## ACCOMMODATION

It is a well recognized fact that the accommodative power decreases with advancing years and while there is no exact relationship between age and accommodation which will hold for all individuals and especially myopes, the following table shows approximately what change is to be expected.

TABLE 4.

ACCOMMODATION AND AGE.

| Age in Years | Accommodation in Diopters |
|---|---|
| 10 | 14 |
| 15 | 12 |
| 20 | 10 |
| 25 | 8.5 |
| 30 | 7 |
| 35 | 5.5 |
| 40 | 4.5 |
| 45 | 3.5 |
| 50 | 2.5 |
| 55 | 1.5 |
| 60 | 1.0 |
| 65 | 0.5 |
| 70 | 0 |