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The Construction and use of the ophthalmometer xxx

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THE CONSTRUCTION AND USE OF THE OPHTHALMOMETER—AN EXPLANATION AND A CORRECTION.

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As the first account, in English, of the construction and use of the ophthalmometer appeared in my Treatise on Astigmatism published in 1887, it seems like going back to somewhat ancient history to bring it up now; and I should not again obtrude it upon a professional public, who have of late been treated to quite an avalanche of papers *pro* and *con* as to the value of the instrument, were it not that that description contains an important error which has not only escaped detection hitherto, but has been perpetuated in other places. So far as I know that is the only description in an English book which gives in any considerable detail the optical principles on which the instrument is constructed, and it is important that those who are studying the apparatus should be correctly informed regarding the arrangements and relations of the parts so as to have an intelligent conception of the phenomena observed[1].

As the ideas in respect to what the ophthalmometer really does seem to be very vague, not to say incorrect, even among those who are using it regularly in practice, it should be understood, in the first place, that its underlying principle is the measurement of the radius of curvature of the cornea by means of an image reflected from its surface. If you know the size of the object, the size of the reflected image and the distance of the object from the reflecting surface, you have all the data at hand for the determination of the radius of a convexly curved surface. Javal's instrument is simply a convenient means for attaining this end.

As the chief, not to say the sole, use of the instrument is for the detection of corneal astigmatism, what is really to be determined is the difference in the curvature of the two opposite meridians, and this is made manifest to the eye of the observer by a difference in the size of the corneal reflection in these two meridians. The optical law is that the surface or meridian of greatest curvature (shortest radius) shall give the smallest image and that of the least curvature and longest radius the largest image; and the instrument of Javal is so constructed as to enable the observer to measure this and the amount of difference in the two meridians at a glance. This it does by a doubling of the corneal image by means of a prism. When the corneal image is 3 mm. in diameter and the telescope is properly adjusted, the edges of these two images, produced by the prism, are in contact, and, conversely, when they are in contact they must each have a diameter of 3 mm. When the double images are separated the corneal image is smaller than 3 mm., indicating a stronger corneal curvature, and when they overlap it is larger than 3 mm. with a greater corneal curvature. In the instrument the lateral boundaries of the object whose

[1]I find, since writing the above, a full account of the optical principles of the ophthalmometer in the last edition of Dr. F. Valk's "Errors of Refraction." He does not fall into the same error that I did, but he accepts the old and incorrect index of refraction (1.35) for the cornea in constructing his table of Dioptry Reciprocals.

corneal image we measure are two white bands (or mires) one of which is graded in steps, and it is so arranged that the amount of over-lapping, when there is any, can be read off on these steps, each one of which represents a dioptry of refraction. And it is just here that the error into which I have fallen comes in.[2] On pages 130 and 131 of my treatise I say: "Moreover the meridian in which there is a crossing of the bands is the less refracting. The fact of the two images overlapping shows that they have a diameter greater than 3 mm., and consequently the surface giving them must have less curvature than that giving them with the edge in contact, and in order to have them thus in contact the object must be made smaller by moving M′ on the arc toward M. If the images of the bands separate in moving the arc from its initial position where they are in contact it shows that the first meridian is the less refracting with a larger radius of curvature." On page 130 in the description of Fig. 38 the same fact is stated, "A, the meridian of greatest curvature, B, meridian of least curvature (longest radius)."

All these statements are correct as regards the instrument as Javal first constructed it, and as it was described by him and also by Gavarret in an article in the *Revue Scientifique*, 15 Juillet, 1882. But when we come to apply these principles to the instrument as now made we find that they do not hold in practice, for we have the *crossing* of the bands in the meridian of *greatest* curvature where the corneal image is the smallest. For instance, the bands being in contact in the horizontal meridian, if the arc is turned to the vertical meridian and there is a crossing of two steps, that signifies that we have an astigmatism of 2D, according to the rule, in which the vertical meridian of the cornea is the most strongly curved and most highly refracting. This seems in direct opposition to the proper optical theory, for in accordance with this, the image being smaller they should separate. This they do, but by the new

[2]For calling my attention to it I have to thank one of my former pupils, Prof. D. K. Shute, M.D., of this city.

arrangement in the later instruments as the image grows smaller the adjacent bands encroach one upon the other as is readily understood from the accompanying figure.

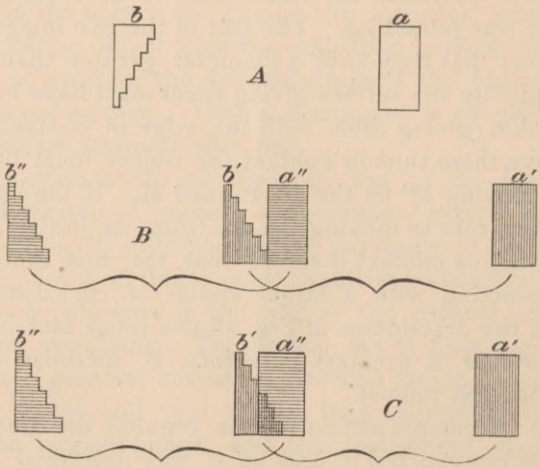

FIG. I.

In A we have the object *a b*, the band *a*, which represents one end being rectangular, the other end *b* having gradations in steps. This is as it appears, one the arc of the ophthalmometer as seen by the examiné. When the cornea is viewed by the observer through the telescope and prism,—the arc being in a horizontal position — the two images of the corneal reflection are seen inverted in the relative positions as shown in B, where a' b' is one image and a'', b'' is the other. The inner side of a'' is in contact with the inner side of b'. The distance between the inner sides of each of these images is 3 mm. when the instrument is properly adjusted. Now let the arc be turned to the vertical meridian which is the more strongly curved and more highly refracting. According to the optical law, the images a' b' and a'' b'' should be smaller, and a' should approach b' and a'' should approach b'', and in doing this of course a'' and b' will overlap as shown in C. And this is how it comes about that we have a crossing of the band in the meridian of shortest radius, greatest curve and highest refraction.

My mistake undoubtedly arose from the fact that I wrote the description after studying Javal's first papers, and did not notice, in reading his subsequent articles, the change he had made in the disposition of the bands. Originally he had the outer side of b'' to be applied to the outer side of a' in the horizontal position which would of course be attended with a separation of a' and b'' when the arc was turned to the vertical position.

The same mistake into which I have fallen has been committed in several treatises and articles written on the instrument that have appeared since the publication of my treatise.

The recently issued work of De Schweinitz has this statement on page 128: "If the image overlaps in the vertical meridian the radius of course is longer in this meridian and there is astigmatism. If the image separates with the bar vertrical, this meridian has a shorter radius than the horizontal." This is, of course, exactly the opposite of the true condition of things. In his text book, Noyes, while giving the correct method of reading, offers no explanation of the principles involved and, besides, is somewhat confusing as to the exact position of the arc, since in one place he speaks of the index of the instrument indicating the position of the arc (the index being at right angles to the arc) and in another of the direction of the arc itself as if they were identical. Würdemann, in a paper published in the *Journal of the American Medical Association*, for August 27, 1892, copies my erroneous statements entire. Koller, in a paper published in the same journal for September 13, 1890, and which purports to give a full and complete description of the instrument, while stating the optical principles correctly, not only makes the same blunder as to the practical application, but illustrates it with a drawing which is exactly the reverse of what it should be for the instruments now in use and which he figures.

It should be remembered that the only thing the ophthalmometer can do is to give data for calculating the radius of corneal curvature. It does not even give us the refraction of the cornea for this can be known accurately only when we have in addition the index of refraction of the corneal tissue[3] and the aqueous humor. In Javal's first paper (*Ann. d'ocul.*, Juil., Aout 1881), he assumed this to be 1.35 and his values for the corneal refraction there given are based on this index. He afterward took what is now accepted, I believe, as the true index, 1.337, but has not, I think, published a revised table. I have myself constructed a table of reciprocal values in refraction on these data[4] which makes them correspond to the reading on the arc of the ophthalmometers now in use.

It would seem from some recently published papers that this really valuable and necessary instrument is in danger of suffering at the hands of a few of its enthusiastic champions, who are claiming reliance upon it to an extent which certainly my experience will not justify. It will not allow us to dispense with the use of a mydriatic in all cases, nor is any one warranted in ordering cylinders in accordance with the reading of the instrument without having verified these readings by other methods. The final resort, as I have always maintained, must be lenses and test-types.

In the majority of cases the corneal astigmatism as shown by the ophthalmometer is the total astigmatism of the eye making allowance for the 0.5 D. astigmatism of the lens, con-

[3]Some one has written of the posterior surface of the cornea as a possible factor, but it should be remembered that the corneal tissue and the aqueous humor are of nearly the same index, and that irregularities of the posterior surface of the cornea could play no important part in changing the refraction.

[4]An analysis of the refraction of 576 healthy human corneæ examined with the ophthalmometer by Javal-Schiötz, "Transactions of the American Ophthalmological Society," 1888.

trary to the rule, but in an important minority it is not; and the longer I work with the instrument the more important a factor I find lenticular astigmatism to be.

The ophthalmometer is a great instrument, but like all other great things, it has its limitations, and we should not, in our admiration, allow these to be lost sight of.