Burnett (S. M.)

With the regards of

Swan M. Burnett

THE GENERAL FORM

OF THE

Human Cornea and Its Relations

TO THE

Refraction of the Eye

AND VISUAL ACUTENESS.

By SWAN M. BURNETT, M.D., Ph.D.,

WASHINGTON, D. C.

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THE GENERAL FORM OF THE HUMAN CORNEA AND ITS RELATIONS TO THE REFRACTION OF THE EYE AND VISUAL ACUTENESS.

By SWAN M. BURNETT, M.D., Ph. D.,
WASHINGTON, D. C.

Ever since the first ophthalmometric investigations of Senff and Helmholtz it has been known that the human cornea is not the section of a sphere; and by numerous measurements since, it has been established that it is not only not an ellipsoid of revolution, but not even an ellipsoid with three axes. The highly asymetrical curve of the cornea is now an accepted fact, and though there are abundant observations to verify it in general terms, it is yet in order to record observations which would tend to show the common law of asymetry, if such there be, in emmetropia, and any variation from this that accompany the ametropic conditions.

The measurements that are herewith submitted were made with the Javal ophthalmometer, and show the curvature taken at the visual axis and at intervals of 5° on each side along the principal meridians up to 20°. In order that those measurements may be expressed in terms with which we are all familiar, I have recorded them in reciprocals of dioptrics of refraction. They were made on corneæ that, so far as I could know, had not undergone any pathological change.

Recently the accuracy of the Javal instrument has been called in question,* and I can see that, in adapting it to its present form as an apparatus which is to be used in daily practice, some sacrifice of its more refined capabilities has been necessary. Yet I doubt if any modification of it will ever be made which will increase its value or reliability as an instrument for promptly determining the refraction of the cornea in its principal meridians with an approximation to accuracy sufficient for all practical purposes. And, in any event, its inaccuracies are not likely to affect, in any very important manner, the comparative measurements of the same cornea by the same instrument, and particularly when the differences in the various readings are so great that we can afford to neglect all values less than 0.5 D. A glance at the table will show at once two important facts which, so far as these statistics go, are unvarying. 1st. That the cornea diminishes in curve and consequently in refraction from the apex towards the circumference, and 2d, that the diminution is much more rapid on the nasal than on the temporal side of the visual axis.† This difference between the refraction at the visual axis and 15° to the nasal side is sometimes enormous, amounting in one case (34) where there was no demonstrable ametropia and V = $\frac{6}{6}$ to 4.5 D. The temporal side of this meridian showed a difference of only 0.5 D. even at 20° from the visual axis. The average difference for the nasal side at 15° is about 2 D.; for the temporal side about 0.5 D. It is also demonstrated that the limit of regular curvature which can be measured is much closer to the visual axis on the nasal side, the difference probably representing the value of the angle *a*.

* Dr. C. Weiland, *Med. News*, June 4, 1892.

† Since this paragraph has been written and all the measurements in my table had been recorded, an abstract of a paper by Dr. H. V. Wuerdemann has been published in the *Am. Journal of Oph.* for June, 1892, which contains statements totally at variance with the facts as recorded in these statistics. "He finds all corneæ highly astigmatic in their periphery and that in most cases the curvature diminishes more rapidly in the vertical than in the horizontal meridians." It is said again that "Degrees of corneal astigmatism of 3 or 4 D. may be produced by the visual line passing eccentrically through the cornea, and in his opinion is one of the principal factors in its production." My measurements would not bear out any such statement in anything like a general application. On the contrary, in astigmatism against the rule, as pointed out by Bajardi (see *infra*) the general astigmatism of the eye diminishes as we move from the center of the cornea towards the periphery. This excentricity is, however, probably a factor in the shifting of the principal meridians along its course from the visual axes towards the periphery (as in cases 1, 2, 10, 11, 18, etc.)

It will be noted also that the highest degrees of ametropia, and especially of astigmatism, are not always associated with the largest differences between the refraction at the axis and periphery, though there is generally a rather close connection between the two. In one case (1) where there was an astigmatism + 4.5 90°, the difference on the nasal side was 4.5 D. at 15°; in another (16) with the same amount of astigmatism it was only 2.5 D. The highest degree of simple M. astig. — 5 D. 180° (4) had a difference to the nasal side at 15° of 3 D., and the same amount in the vertical meridian downward.

In the two cases of mixed astigmatism (8 and 31) the corneal curve was what may be considered normal in the horizontal meridian, but with a slight excess of normal difference in the vertical meridians.

In the three eyes with astigmatism against the rule (10, 14, 24), there was not any material change from the normal in the horizontal meridian, but in two of them (10 and 24) the diminution of the curve in the upper half of the vertical meridian was rather more rapid than usual.* The curves of the cornea after cataract extraction are given in case No. 35. These measurements were taken one month after the operation, and the healing, though good, had been slow. The astigmatism, as is always the case after cataract extraction, is contrary to the rule, but in excess of what it usually is at this date after the operation. It will be observed that the cornea suffers its greatest change at the upper inner quadrant. I should state here, however, that in a case which I measured since the table has been made in which the healing had been perfect, the cornea at the end of three weeks was still more irregular than in this instance.

The important deduction to be drawn from a study of these measurements is that the outer side of the cornea is much more regular in curve than the inner, and the main practical inference is that in making an iridectomy for optical purposes the place of election is under this part of the cornea as being more regular throughout a greater part of its extent than the inner side.

* P. Bajardi has recently contributed an article on this subject to the *Annali d' Ottalmologia*, Anno xx, Fasc. 4, 1891.

Number	Name and Eye.	Horizontal.									Vertical.									Refraction of the Eye, Visual Acuteness, Remarks, Etc.
		Nasal.					Temporal.				Inferior.					Superior.				
		0	5	10	15	20	5	10	15	20	0	5	10	15	20	5	10	15	20	
1	Mrs. W.,	r.	22.	21.	20.	17.5	16.	22.	22.	21.5	21.	28.	27.5	27.	26.	26.	27.	28.	27.5	∞	+ 4.5 90 = 5/18. The principal merid. upward changed from 90 to 65° at 20°.
2	Miss B.,	l.	24.	23.	22.5	22.	20	5 24.	24.	23.	23.	25.	25.	24.	23.	23.	24.	23.5	23.	22.	+ 4 ◯ + 0.75 90 = 5/9. Gradual change on nasal side to 60° at 20°.
3	Mrs. W.,	l.	22.	22.	21.	20.	19.5	22.5	22.5	22.5	22.	26.	25.5	25.	24.	24.	26.	25.	25.	24.	+ 7 ◯ + 2.90 = 5/18.
4	Miss W.,	r.	22.	21.	20	5 18.	17.	22.	22.	22.	21.5	26.5	26.5	26.	25.	25.	26.	25.	23.	∞	− 5.180 = 5/12.
5	Miss G.,	l.	22.	20.	19.	15.	∞	22.	22.	22.	20.	27.5	27.	26.5	26	25.	27.5	27.	26	5 24.	+ 1 ◯ + 5.90 = 5/8.
6	Miss D.,	r.	25.	24.	23.	21.	∞	23.	23.	23.	23.	26	5 26.	26.	25.	24.	26.5	25.	25.	25.	+ 0.5 90 = 5/6.
7	Miss O.,	l.	21.	20	5 19.	16.	∞	21.	21	20.5	20.5	27.	26.	25.	24.	24.	26.	26.	25	∞	+ 4.7 5 = 5/18.
8	Miss A.,	l.	21.	20.	19.5	19.	18.	21.	21.	21.	20.5	26.5	26	5 26.	25.	24.	26.5	26.5	25.	24.	+ 2 ◯ + 3 5 180 = 5/18.
9	Mr. M.,	r.	26.	26.	26.	25.5	∞	26.	26.	25.	23.	27.	26	26.	25.	25.	26.	26.	25.	24.	V = 5/6. Em.
10	Miss G.,	r.	24.	24.5	23.	21.	∞	24.	24.	23.5	23.	22	22.	22.	22.	∧	21.	20.	19.	∞	+ 2 180 = 5/12. Hor. merid. changes on temporal side from 180° to 120°.
11	Miss J.,	r.	28.	28.	∞	∞	∞	28.	26.	25	∞	23.5	23.	23.	22	5 26.	24.	24.	24.	24.	− 2 ◯ − 320 = 5/12. Hor. merid. 15°, vert. 105, changing to 90 at 15° up.
12	Mrs. W.,	r.	25.	24.5	24.	22.	∞	25	25.	24.5	23.	25.5	25.5	25.	∞	∞	25.5	25.	25.	∞	+ 4 = 5/16.
13	Mr. H.,	r.	21.	21.	20.5	19.	∞	21.	21.	20.5	20.	22.	21.5	21.	19.5	∞	22	21.	20.	20.	+ 2.75 = 5/9. Hor. merid. out changes gradually to 60° at 20°.
14	Mrs. F.,	r.	23.5	23.5	23.	22.5	22.	23.5	23.5	23.5	23.5	23.	23.	22.5	22.	21.5	23	5 23.5	23.	22.5	− 5 ◯ − 1.25 90 = 5/6.
15	Mrs. K,	l.	20.	19.	18	5 18.	17.5	20.	20.	20.	19.5	21.	20.5	20.	19.5	18.5	21.	21.	20	5 20.5	− 0.75 ◯ − 0.5 180 = 5/6.
16	Mrs. P.,	l.	21.	20.5	20.	19.5	19.	21.	21.	21.	21.	25.5	25.	24.5	24.	23.	25.	24	5 24.	23.	+ 4.5 90 = 5/18.
17	Mr. C.,	l.	25.	24	23.	22.5	∧	25.	25.	24.5	24.	26.5	25.	24.5	24.	23.5	26.5	26.	25.	25.	− 0.545 = 5/6.
18	Mrs. S.,	l.	22.5	22.	21.5	20.	19.5	22	5 22.5	22.	21.5	22.	22.	22.	21.5	21.5	22.	22.	21.5	21.5	E. V. = 5/6 + horizontal merid. changes to 75° at 20° in., and to 105° out.
19	Mr. M.,	l.	20.5	20.	19.	18.5	18.	20.5	20.5	20.	20.	20.5	20.5	20.5	20.	20.	20	5 20.5	20.	20.	− 0.590 = 5/6. Hor merid. changes on nasal side to 45° at 20°.
20	Miss S,	r.	20.5	20.5	20.	18.5	16.	20.5	20.5	20.	18.5	21.	21.	20.	20.	20.	20	5 20.	20.	∞	E. V. = 5/6 + hor. merid. changes gradually on temp. side to 70° at 20°, and the vert. merid. up. to 150° at 20°. [at 20° temp.
21	Miss K.,	r.	22.	21	5 21.	20.	18.	22.	22.	21	5 21.	22.5	22.5	22.	22.	21.	22.5	22.	22.	21.	E. V. = 5/5. Hor. merid. changes gradually to 150° at 20° nasal, and to 150
22	Mr. L.,	l.	21.	21.	20.5	20.	19.	21.	21.	21.	20.5	22.	22.	21.5	21.5	21.	22.	22.	21.5	20.	V = 5/6 with + 4. Hor merid. changes to 150° nasal at 20°.
23	Miss F.,	l.	25.	24	5 24.	23	5 22.	25.	25.	24.5	24.	25.5	25	5 25.	24.	23.5	25.5	25	5 25	5 25.	V. 5/5 E. Hor. merid. changes to 135° at nasal side at 20°.
24	Mr. A ,	l.	23.5	23.	22.	20.5	17.5	23.5	23.5	23.	22.5	23.5	23.	22.5	22.	21	23.5	23.	21.	19.	− 1.70° V = 5/5. Hor. merid. changes to 135° at 15° temporal.
25	Mr H ,	l.	22.	21	5 20.5	19.	17	5 22.	21.5	21.	20.5	23.5	23.5	23.5	22.	20.	23.5	23.	22.	∞	+ 1 90 V. 5/5. Hor merid changes to 155° at 20° nasal.
26	Miss Mc.,	l.	23.	23.	22.	20.5	17.	23.	22.5	22.	21	24.	23.5	22.	21.5	20.	23.5	23.	21.	20.	+ 1 ◯ + 0 5 90. V. = 5/9. Hor. merid. changes to 150° at 20°.
27	Mr. C.,	l.	20.5	20.	19.5	18.	∞	20	5 20.5	20.	19.5	22.	21.5	21.	21.	20.	22.	21.	20.	19.	V. = 5/5. Hor. merid. changes to 155° at 20°; vert. merid. to 75° at 20°.
28	Miss H ,	l.	23	5 23	5 23.	22.	20	5 23.5	23.5	23.	22.5	23.	23.	22.5	22.5	22	5 23	5 24.	24.	23 5	E. V. = 5/5.
29	Mr. F.,	l.	19	5 19.5	19.	18.	16.	19	5 19.5	19.	18.5	23.	22.5	22.	21.	20.5	22	5 22.	21.	20.5	+ 2 75 ◯ + 2.5 90. V. = 5/12.
30	Mrs. P ,	r.	24.	23.5	23.	22.	22.	24.	24.	23.5	22	5 24.	24.	23.5	23.	22	5 24.	24.	23.5	23 5	E. V. = 5/5.
31	Miss S.,	l.	20	19	17.5	17.	∞	20.	20.	19	5 19.	24.	24.	24.	23	5 23.	24.	24.	24.	23 5	+ 1.75 ◯ − 4,1 65. V. = 5/18. Meridians 75° and 165°.
32	Mr O.,	r.	22.	22.	21	5 20.	19.	22.	22.	21.	21.	23.	22.5	22	5 22.	21.5	22.	22.	22.	21.5	+ 0.75 ◯ + 0 5 90. V. = 5/5.
33	Mr. S ,	l.	22.5	22.	21	5 21.	20.	22.5	22	5 22.	21.5	22.	22.	22.	21.	20.	22	22	21.5	21.	E. V. = 5/5
34	Miss P.,	r.	23	5 23.	21.5	19	∞	23	5 23.5	23.	23	24.	24.	23.5	23.	22.	24.	23.5	23	23.	V. = 5/6 E. Hor. merid. changes to 150° at 20°.
35	Mr. H.,	l.	31.	30.	27.	∧	∞	31.	31.	29.	27.	20	20.	20	5 21.	21.5	20.	21.	∞	∞	Cataract. Ext. end of 1 month without iridectomy, upward incision. Slow
36	Mr. M ,	r.	25.5	24.5	24.	22.	20.	25.5	25.5	25.5	25.	24.	26.	25	5 24.	22.5	20	5 25.	25.	24 5	− 4 ◯ − 0.5 75. V. = 5/9. [healing, but no excessive inflammation.
37	Mr F.,	l.	22.5	22.	21.	19.	∞	22.5	22.5	21.	∧	22.5	22.5	22.	21.5	21.	22.	21.	19.	∞	+ 0 5 180. V. = 5/5.
38	Mr. B.,	l.	24.	23	5 22.5	21.	∞	24.	24.	23.5	23	24	5 24	5 24.	25	5 23.	24	5 24.	23.5	22 5	V. = 5/5. E.
39	Mr. W.,	r.	24.5	24.	23	22.	21.	24	5 24.	23.5	22.	23.5	23.	22.	21.	21.	24	22.5	21.5	∞	− 1 ◯ − 2.75 90. V. = 5/12.
40	Mr. S.,	r.	25.5	25.	24	21.	∞	25.	24.5	24.	∞	25.	24.5	23	5 22.5	∞	24.5	24.	20.	∞	− 2.105. V. = 5/6.
41	Mr F.,	l.	21.5	21.	20.	19.5	∞	21	5 21.	20.5	20	5 25.	24.	23.	21.5	∞	25.	24	5 24.	∞	− 1.75 ◯ + 3.90. V. = 5/9.
42	Miss H.,	r.	22.	21.	21.	19	∞	22.	22	21	5 21.	26.	25.	24.	22.	21.	26.	25.5	24.	23.	V. = 2/200. No glasses materially improve.

The numbers represent the readings on the right arm of the arc of the ophthalmometer. To have the exact refraction in dioptries, 20 must be added to the number so recorded, thus: $20 + 22 = 42\ D$. The sign ∞ signifies that the image was too blurred to allow an accurate reading.

There seems to be but little difference between the upper and lower portions in that particular. Incidentally these tables also corroborate what I said when I first brought the ophthalmometer to the notice of the profession in this country in 1885, and which I have ever since insisted on,* that while this apparatus of Javal is, on the whole, the most valuable single instrument at our command in working out astigmatism, it is not to be relied upon to the exclusion of other means, since it gives us no indication of the amount of lenticular astigmatism, the frequency of whose existence this apparatus has itself been mainly instrumental in establishing. It would seem from some recent statements that the ophthalmometer is now in greatest danger in the house of its injudicious friends.

I cannot say that these statistics give us any certain or reliable knowledge regarding the cause of the diminished visual acuteness in ametropia, and particularly in that of high degrees, for, as mentioned at the beginning of this paper, they fail to show any constant association between a diminished visual acuteness and an abnormal corneal curve.* But they do give, I think, an explanation of the very much reduced acuteness of vision with a dilated pupil, as compared with that of normal size which we so frequently meet with. In fact, we cannot but wonder that with so much and so constant an irregularity of corneal curve that we are possessed of the amount of visual acuteness we do enjoy, and we again wonder, without, however, denying absolutely the fact, how very weak lenses can give by their optical action the amount of relief to asthenopic symptoms which they seem, in some cases, to do.

* Treatise on Astigmatism, 1887. Knapp's Archives, 1885. Trans. Amer. Oph. Soc, 1888.