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REFRACTIVE KERATOPLASTY - VERGENCY CALCULATIONS

BY

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INTRODUCTION

Refractive keratoplasty is being undertaken in a clinic in Bogota, Colombia and at the Eye Bank Laboratory of the Manhattan Eye, Ear and Throat Hospital in New York. The technique, as practiced, consists of removing a corneal section with an instrument called the microkeratome, carving the section and replacing it on the eye.

Dr. José I. Barraquer of the Instituto Barraquer de America, carves his sections on a lathe, the technique resembling the initial step in the manufacture of contact lenses. Martinez and Katzin [1] have developed techniques of flat slicing and carving on a freezing microtome. This paper will concern itself with the calculations in the technique of lathe-carving the corneal section.

Barraquer [2], [3], in his original work, has developed a calculation rationale which needed an empirical correction to insure relative accuracy in the outcome, insofar as refractive considerations are concerned. It is the goal of Dr. Herbert M. Katzin [4] and his group * (see footnote) to precalculate the parameters concerned in the successful completion of this technique.

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* a team of researchers developing techniques and refinements for refractive keratoplasty at the Manhattan Eye, Ear & Throat Hospital.

SURGICAL TECHNIQUE

A brief description of the surgery might be in order at this time. To begin, a speculum is inserted and fixed. A pneumatic ring (figure Nº 1) is then affixed to the eye. This ring is actually a cylinder with a disc top. The disc is perforated by a central hole. The open end of the cylinder is placed on the globe. This cylinder is preselected by dimension based on certain considerations which are extraneous to the discussion at hand. The pneumatic rings are available in sets of different sizes for different topographies. One of the considerations in the selection of the appropriate size ring is that the cornea shall protrude through the perforation in the disc a top the cylinder, and the fit will produce sufficient vacuum for fixation. This prorusion shall be sufficient so that almost the entire cornea will protrude and when the cornea is applanated, the diameter of applanation shall approximate 9 mm. Therefore, as the cornea is pressed down by a flat surface, somewhat above the level of the disc, the diameter of the cornea that is flattened by the applanation device will be 9 mm. The top of the disc portion of the pneumatic ring contains a small track in the form of a dovetail.

After the correct size ring has been determined, it is placed in its position on the glove and suction is applied. This section will have the function of affixing the ring tightly to the globe. If the ring is moved, the glove will move with it so that the orientation of the protruding cornea is constant with respect to the ring.

The microkeratome is constructed on the principle of a carpenter's plane. The front portion of the instrument serves as an applanation device. It presses down the protruding section of cornea so that it approximates a flat surface. The blade that protrudes through the plane is electrically driven so that it rapidly moves from side to side as the microkeratome is advanced. This action is actually reciprocating on the part of the blade. As the blade is advanced (figure Nº 2), a disc is shaved from the cornea which is 8 to 9 mm. in diameter, round and with parallel surfaces. This disc is then removed from the microkeratome, and placed in a solution containing 10% glycerine and from 0.5 to 1.0% of green dye to induce color into the section. The solution containing the section is then placed in a chamber at 0° C. to prepare it for freezing. It is removed from this chamber after 10 minutes and then the corneal disc is removed from the solution and placed on a concave lap in a lathe. The disc is then spun on the lap to flatten it out, drive the excess solution from the tissue and help center it on the lap. The lathe has been fitter with tubing for freezing gas to act upon the lap and the cutting tip. The freezing gas is then applied and the posterior surface of the corneal section (exposed to the cutting tip) is then carved to a new radius. It is not only necessary to carve a new radius - it is also necessary

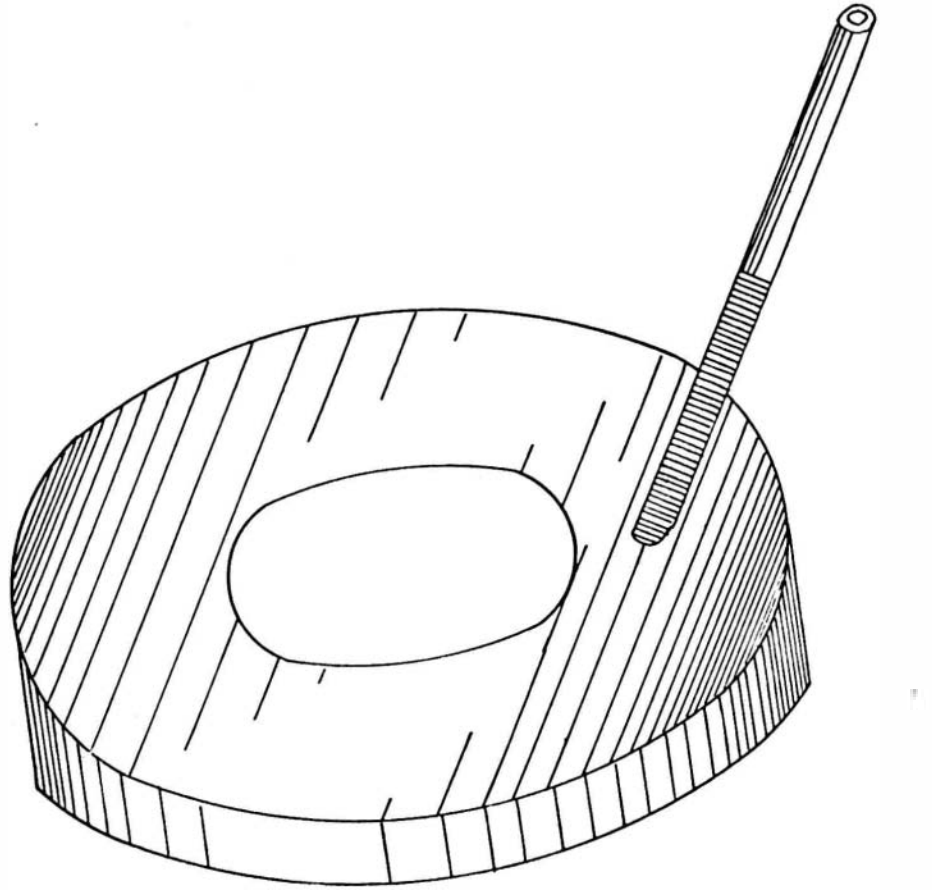

Fig. 1. PNEUMATIC RING through which suction is introduced as it is placed on the globe, to provide fixation and a base for the microkeratome.

to control the remaining edge or center thickness of the corneal section (to correct myopia or hyperopias the case may be), and also to control the diameter of the carving itself. It is sometimes not desireable to carve to the periphery of the corneal section.

After the carving has been completed, the frozen lap with corneal section affixed is removed from the lathe and the corneal section is bathed with normal saline solution at a temperature of 37° C. This serves to thaw the section, after which it is replaced on to its bed and sutured back to the eye.

The stitches are removed after 7 days and the cornea epithelizes 48 hours later.

INITIAL CONSIDERATIONS

There are a number of approaches in calculating the appropriate changes in carving the cornea by the lathing technique. The best overall approach appeared to be the consideration of the disc in air after its removal from the cornea itself. Two basic results are necessary to determine the accuracy of the carving. The first is the refractive power of the disc in air before surgery, and then the calculation of the refractive power in air after surgical intervention. Some assumptions are necessary before this approach is used.

Firstly, it must be assumed that the surfaces of the corneal disc are parallel. Even though the cornea is applanated by the microkeratome in advance of the cutting edge of the blade, it is somewhat doubtful that the slice will have exactly parallel surfaces. Since the force of aplanation at the pole will exceed the force of aplanation at the periphery, it is likely that there will be some compression of the corneal tissue at the pole to a greater extent than at the periphery. It is likely, then, that the corneal section, rather than having parallel surfaces will actually be thicker at the center. This projection applies to the relaxed state of the section. When the compression is released as the section is separated from the body of the eye, it is advanced that the portion which has been subjected to the greater compression will assume a greater thickness than the portion subjected to a minimum compression - as a result of the resiliency of the tissue.

The second assumption to be made is with respect to the optical homogeneity of the section. The literature states that the layers of the cornea are isoindicial. This assumption, therefore, appears to be fairly safe.

The third assumption is made with respect to the thickness of the section. The microkeratome that is currently in use is designed to cut a section of 0.4 mm. in thickness. The thickness, however, is subject to some variation. This variation will occur as a result of either technique or changes in intraocular tension. The

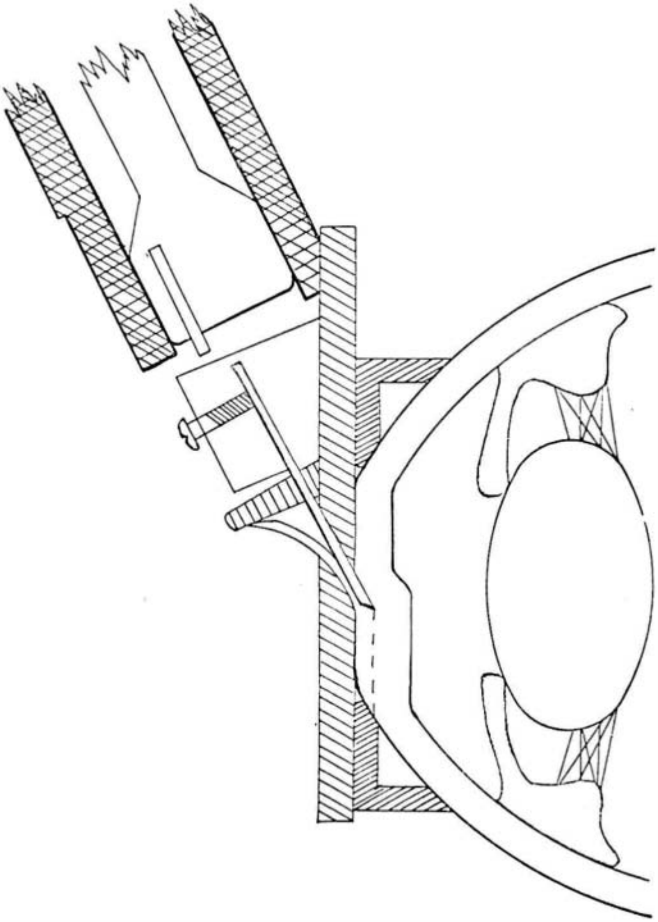

Fig. 2. **THE MICROKERATOME** advancing across the pneumatic ring shaving a corneal disc from the eye.

intraocular tension is determined before the microkeratome is applied to the ring. The latest technology dictates an optimum intraocular tension of from 40 to 60 mm. of mercury before the slice is taken. This high intraocular tension is a direct consequence of the suction applied to the pneumatic ring. The intraocular tension may be controlled by varying the degree of vacuum from the suction pump and motor. The thickness assumption of 0.4 mm. is merely made for the initial analysis. It will be shown later that the actual thickness for the purposes of the initial calculation is unimportant, as it fall out of the calculation after the first comparisons are made. The later phases of the calculation do, however, require a knowledge of the thickness of the corneal section in each instance.

The fourth assumption to be made is that the corneal section will assume a relaxed state identical in curvature to its form before it was removed. Therefore, if the K reading displayed a spherical cornea of 7.5 mm. radius before the surgery, it is assumed that after the section is removed it will display a radius of 7.5 mm. in air with respect to its anterior surface.

OPTICAL CALCULATIONS

Before Surgery

The following paraxial formulae may be applied in arriving at the posterior vertex power of the corneal section before it has been subjected to carving (figure Nº 3):

$$r_p = r_a - t \tag{1}$$

$$f_{1'} = \frac{r_a}{n' - n} \tag{2}$$

$$f_2 = f_{1'} - t/n' \tag{3}$$

$$F_2 = 1/f_2 \tag{4}$$

$$F_p = \frac{n - n'}{r_p} \tag{5}$$

$$D_{bs} = F_2 + F_p \tag{6}$$

where:

r_p is the mean radius of the posterior surface,

$^*r_a$ is the mean radius of the anterior surface (see footnote),

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* the mean radius of curvature of the cornea shall be taken to be a value midway between the radii of two principle meridians of the K reading (see example Nº 1).

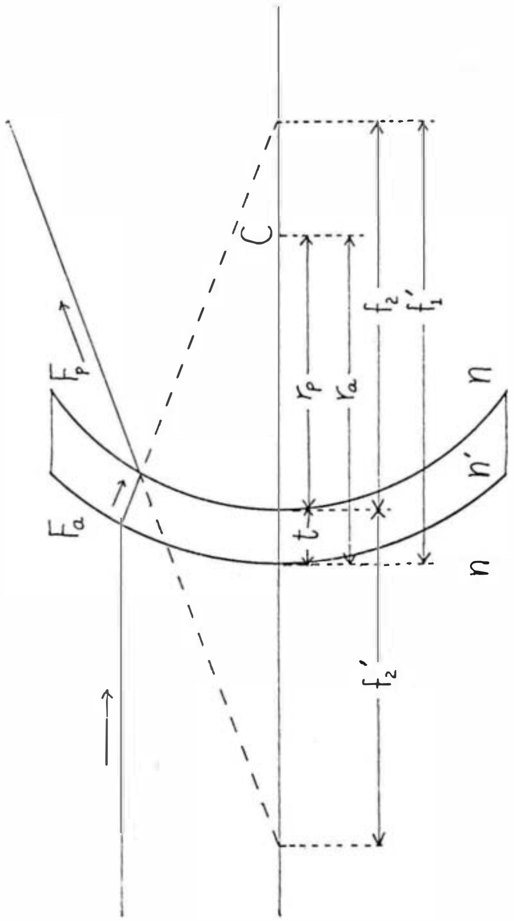


Fig. 3. A ray of light enters the corneal section parallel to the axis, refracted by the section, with the parameters as defined in the discussion, appropriately illustrated.

f_1' is the focal length after refraction at the first surface,

f_2 is the focal length before refraction at the second surface,

F_2 is the vergency before refraction it the second surface,

F_p is the dioptric power of the second surface,

D_{bs} is the dioptric power of the corneal disc, in air, before surgery,

n is the index of refraction of air,

n' is the index of refraction of the cornea, and

t is the thickness of the corneal section.

These six equations may be combined into the following single formula:

$$D_{bs} = \frac{n'(n' - n)}{r_a n' - t(n' - n)} + \frac{n' - n}{r_a - t} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (7)$$

Example Nº 1: K reading: -2.50 cylinder axis 180, axis meridian 42.00. This would mean that the horizontal reading is 42.00 diopters and the vertical reading 44.50 diopters. The mean value in diopters is 43.25, and this corresponds to a radius of 7.80 mm., using the assumed keratometer index of 1.3375.

Example Nº 2: K reading -2.50 cylinder axis 180, axis meridian 42.00, thickness of corneal disc: 0.4 mm.

$$D_{bs} = \frac{1.376(1.376 - 1.000)}{.0078(1.376) - .0004(1.376 - 1.000)} + \frac{1.000 - 1.376}{.0078 - .0004}$$

$$D_{bs} = 1.921$$

This value for D_{bs} represents the posterior vertex power of a corneal disc which has been removed from the eye possessing the parameters as stated, assuming, of course, parallelism of the surfaces, and optical homogeneity.

This disc may be placed on a lathe, frozen with the anterior surface in opposition to the lap and have its posterior surface carved to a new radius. For the purpose of optical investigation, however, it is better to make a working assumption that it will be the anterior surface that is carved. In making this assumption, it must be realized that the posterior surface would be frozen to a lap matching in radius the bed of the cornea so that when it is thawed and removed from the lathe, and then sutured back to the eye, the corneal section will not undergo any bending which would, subsequently, change its dioptric power.

AFTER SURGERY

It is now incumbent to discover the dioptric power of the corneal section after its anterior surface is carved. The vertex power may be calculated by the derivation of two final formulae.

Let figure Nº 4a represent a corneal section after it has been removed from the eye. The shaded areas represent those portions of the sections eliminated by carving. Figure Nº 4b represents that situation where the carving is to compensate for myopia and figure Nº 4c represents that situation where the carving is to compensate for hyperopia.

Myopia

In myopia, which will be considered first, the area to be carved away represents a convex meniscus lens with a knife edge. Figure Nº 5ª demonstrates the following relationship:

$$s_p = s_a - c \quad \text{..........} (8),$$

where:

c is the thickness of the section to be carved away,

s_a is the sagitta of the original mean anterior corneal radius, and

s_p is the sagitta of the new mean anterior corneal radius.

The formula for the sagitta of an arc may be derived from figure Nº 5c by solving right triangles, and is:

$$s = r - \sqrt{r^2 - y^2} \quad \text{..........} (9),$$

where:

y is half the chord of the arc, and represents the semi-diameter of the zone to be carved.

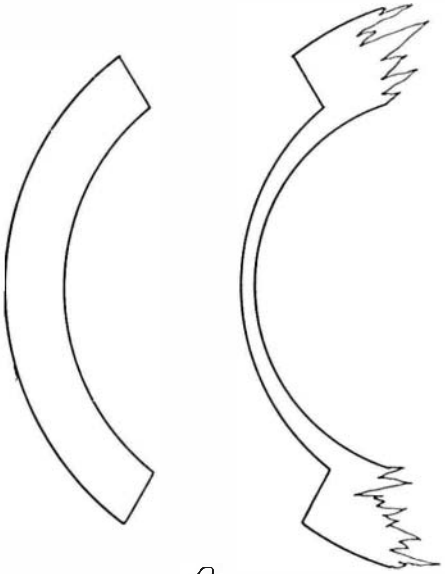
By combining (8) and (9), the following formula is derived:

$$s_p = r_a - \sqrt{r_a^2 - y^2} - C \quad \text{..........} (10).$$

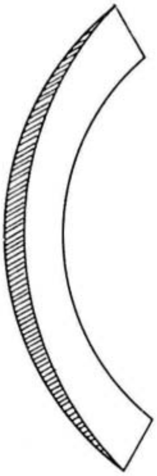
where:

s_p is the sagitta of the posterior arc and of the new anterior radius.

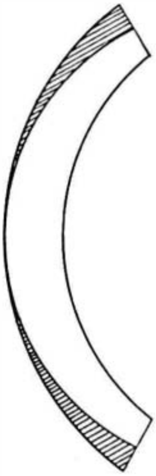
The formula for the calculation for the radius of an arc may also be derived from figure Nº 5c by solving right triangles, and is:



a



b



c

Fig. 4a represents a corneal section removed from the body of the cornea.

Fig. 4b represents the corneal section, the shaded area represents that portion of the cornea to be carved away (schematically but not actually), to correct for myopia.

Fig. 4c represents the corneal section, the shaded area represents that portion of the cornea to be carved away (schematically but not actually), to correct for hyperopia.

$$r = \frac{s^2 + y^2}{2s} \qquad \ldots\ldots\ldots\ldots (11).$$

Adding subscripts for identification, therefore, in the calculation of the new anterior radius after carving, the following formula is derived:

$$r_{na} = \frac{s_p^2 + y^2}{2s_p} \qquad \ldots\ldots\ldots\ldots (12),$$

Where

r_{na} is the new anterior radius after carving.

The following formulae may be combined: (10), (12), (1), (2), (3), (4), (5) and (6), with a modification to (6) as follows:

$$D_{as} = F_2 + F_p \qquad \ldots\ldots\ldots\ldots (13),$$

where:

D_{as} is the dioptric power of the corneal disc after surgery. The combined equation is:

$$D_{as} = \frac{2n's_p(n' - n)}{n'(s_p^2 + y^2) - 2s_p(n' - n)(t - c)} + \frac{n - n'}{r_a - t} \qquad \ldots\ldots\ldots\ldots (14).$$

Hyperopia

In hyperopia, the area to be carved away represents a concave meniscus lens with a zero center. Figure Nº 5b demonstrates the following relationship:

$$s_p = s_a + c \qquad \ldots\ldots\ldots\ldots (15).$$

The following formula is derived by combining (9) and (15):

$$s_p = r_a - \sqrt{r_a^2 - y^2} + c \qquad \ldots\ldots\ldots\ldots (16).$$

The following formulae may be combined to arrive at the combined equation, representing the dioptric power of the corneal disc after surgery to correct hyperopia: (16), (12), (1), (2), (3), (4), (5) and (13):

$$D_{as} = \frac{2n's_p(n' - n)}{n'(s_p^2 + y^2) - 2s_pt(n' - n)} + \frac{n - n'}{r_a - t}$$

The change in dioptric power from before to after surgery is indicated by the expression:

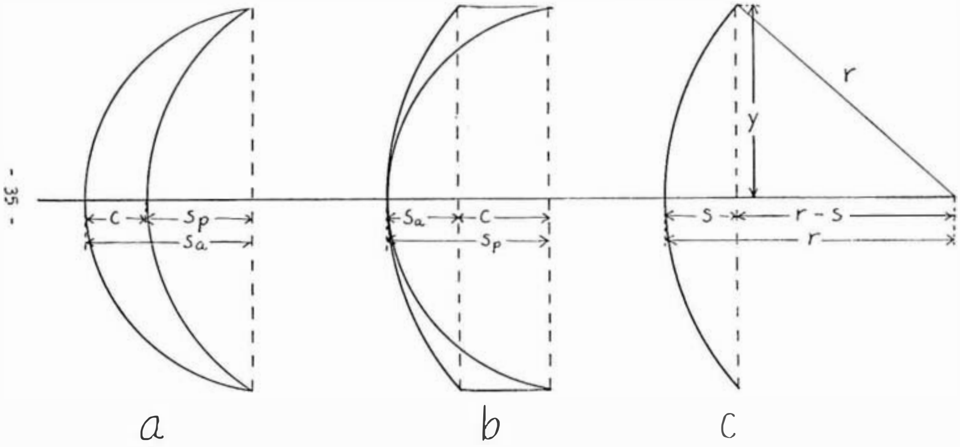


Fig. 5a represents a convex meniscus lens demonstrating the relationship between the sagittae of the anterior and posterior surfaces and the center thickness.

Fig. 5b represents a concave meniscus lens demonstrating the relationship between the sagittae of the anterior and posterior surfaces and the center thickness.

Fig. 5c demonstrates the relationship between an arc's radius, its semi-chord and its sagitta.

$D_c = D_{as} - D_{bs}$ ....(18),

where:

D_c is the net change in vertex power of the corneal section, and, consequently, that of the eye, as a result of surgical intervention.

In referring to equations (7), (14) and (17), it may be seen that they each contain two terms, the second of which is identical in all three equations. In (18), therefore, a modification may be made to simplify, in the following manner:

$D_c = D_{as}$ (first termP — D_{bs} (first term) ....(19)

DERIVATION OF TABLES

Rather than laboriously calculate for each operation, tables may be calculated for the value D_c. The number of variables that might be used in the calculation of tables may be examined at this point. The normal limits of corneal radius measurement may be taken as the limits of the Bausch & Lomb keratometer, for instance. This ranges from 36.00 diopters at the flattest to 52.00 diopters at the steepest. Therefore, at increments of 0.25 diopters, there would be 64 values for r. The usual maximum and minimum limits of the area to be carved are 6 and 8 mm. diameter circles. Proceeding in increments of 0.25 mm., a total of 9 values could be substituted for y. The maximum thickness consistent with surgical considerations, may be taken to be 0.4 mm. for the corneal disc before carving. The maximum reduction in either center or edge thickness is considered to be 0.28 mm. leaving 0.12 mm. at the thinnest point of the section after carving. Proceeding in increments of 0.01 mm., a total of 28 values may be substituted for c. Therefore, tables would have to be calculated which would contain more than 30,00 answers. In order to avoid this task, short cuts were evolved without materially affecting the outcome.

Linearity of "c"

The linearity of the value "c" was tested in the following manner: values were assigned for the different variables and the net change in vertex power was calculated, using different values for c in a number of calculations. The first calculation will be explained and the others will follow:

Example Nº 3: A corneal section with the following dimensions is carved in such a manner as to reduce its center thickness by 0.01 mm. in order to correct myopia:

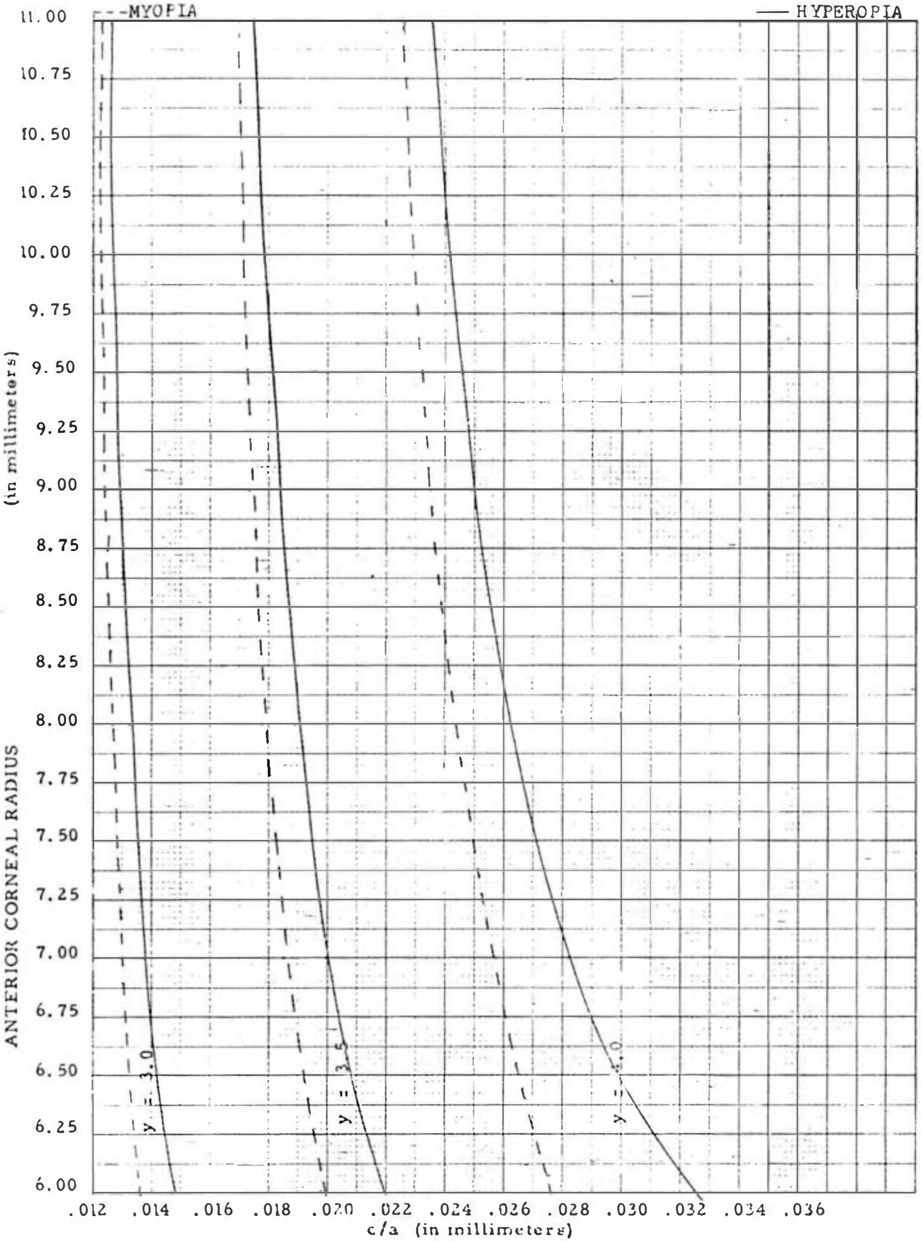
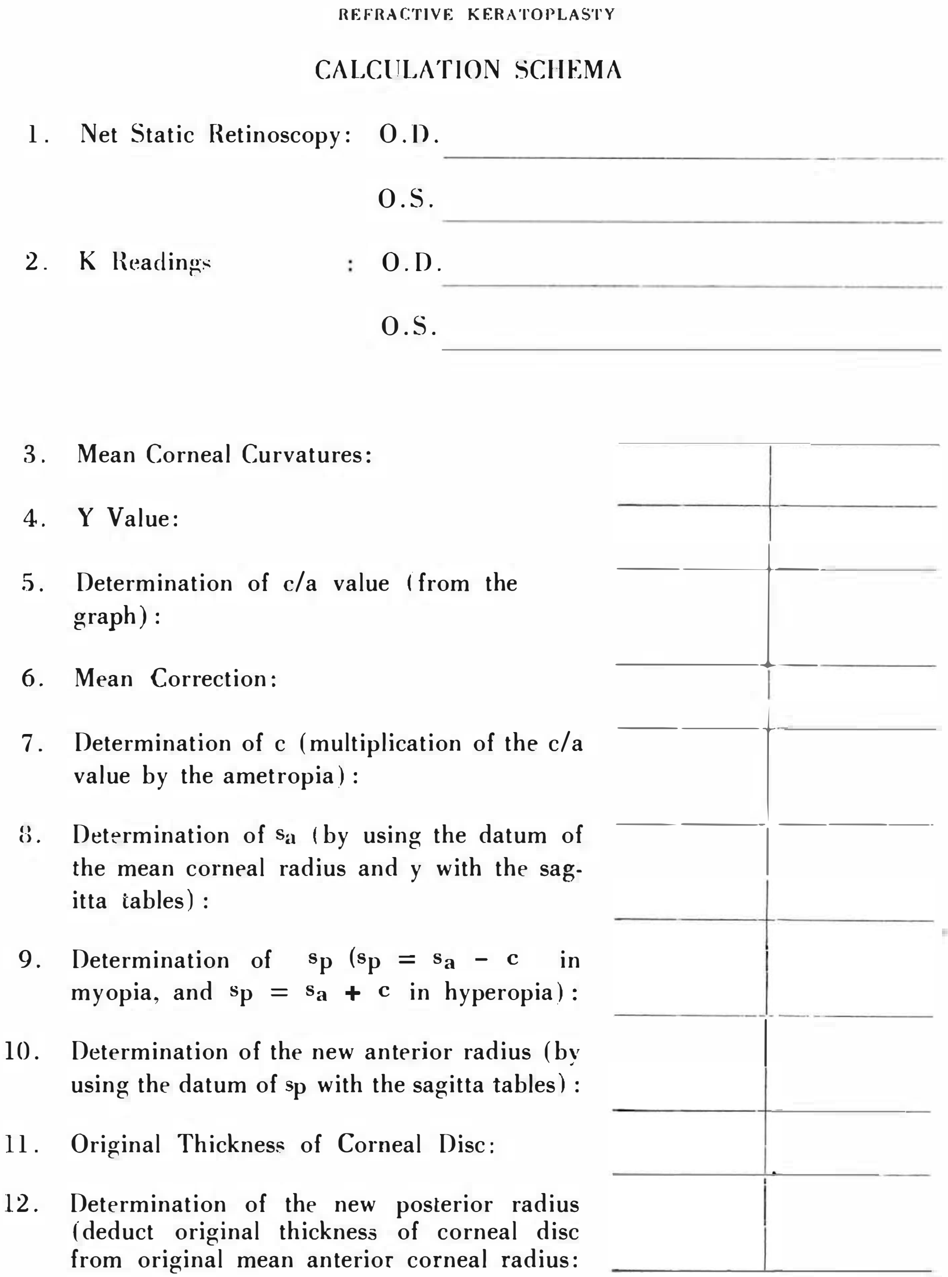


Fig. 6. A graph demostrating the relationship between the mean anterior corneal radius and the c/a value. This graph reflects the information in table Nº 3.



REFRACTIVE KERATOPLASTY

CALCULATION SCHEMA

1. Net Static Retinoscopy: O.D. ____________________

O.S. ____________________

2. K Readings : O.D. ____________________

O.S. ____________________

3. Mean Corneal Curvatures:		
4. Y Value:		
5. Determination of c/a value (from the graph):		
6. Mean Correction:		
7. Determination of c (multiplication of the c/a value by the ametropia):		
8. Determination of s_a (by using the datum of the mean corneal radius and y with the sagitta tables):		
9. Determination of s_p ($s_p = s_a - c$ in myopia, and $s_p = s_a + c$ in hyperopia):		
10. Determination of the new anterior radius (by using the datum of s_p with the sagitta tables):		
11. Original Thickness of Corneal Disc:		
12. Determination of the new posterior radius (deduct original thickness of corneal disc from original mean anterior corneal radius:		

Fig. 7. The form used by the Katzin group for biological experimentation to calculate the values necessary for the appropriate lathe-settings and the choice of lap for the carving of the corneal section.

original mean radius (K reading mean) : 11.066 mm.,
diameter of portion to be carved (2y) : 4.0 mm.,
thickness before carving : 0.4 mm.,
relationship of surfaces : parallelism.

The results of the calculation follow:

vertex power of the section before carving : -0.935
vertex power of the section after carving : -1.386
net change in vertex power as a result of carving: -0.451

The same calculations were made with different c values and the resultant net changes are shown in table Nº 1.

It may be seen that each additional reduction in center thickness, there is an additional increment in the increase in change.

It may be seen, in the last column, that the change of -13.490 diopters as a result of 0.30 reduction in center thickness averages 0.449 for each increment of 0.01 mm. change in center thickness. If the assumption of c's linearity is made, therefore, the range of error in calculation is plus or minus 0.004 diopters in the resultant calculation. It was assumed, therefore, that the value for c may be considered lineal for the purposes of the calculations for this procedure.

Effect of Thickness Reduction

A number of calculations were made, all of which used an assumed value for c of 0.1 mm. These calculations used three different y values: 3.0 mm., 3.5 mm. and 4.0 mm. They also used six different assumed radii of curvature from 6.00 mm. through 11.00 mm., at increments of 1.00 mm. The calculations were made for both myopia and hyperopia (table Nº 2).

Each of the calculations yielded the following information: if the center or edge thickness was reduced 0.1 mm., with the particulary and the particular r that was assumed the net change in vertex power was determined. The results of this series of calculations appear in table Nº 2.

Derivation of Graphs

Any of the resultant calculations may be selected to illustrate the next principle. The calculation for the net change in vergency for a cornea of mean radius of 6.00 mm., with a y value of 3.0 mm., is equal to 7.406 diopters, according to

TABLE I

Calculation of the increments in changing power by increasing the c value.

c value :	0.010	0.020	0.030	0.040	0.050	0.300
D_{as} :	—1.386	—1.827	—2.269	—2.712	—3.155	—14.425
D_{bs} :	—0.935	—0.935	—0.935	—0.935	—0.935	—0.935
net change :	—0.451	—0.892	—1.334	—1.777	—2.220	—13.490
minus previous net change:		—0.451	—0.892	—1.334	—1.777	÷ 30
increment		0.441	0.442	0.443	0.443	0.447

TABLE II

Calculation for net change in power of corneal disc of thickness 0.4 mm. by reducing center or edge thickness 0.1 mm. with different y values.

EDGE REDUCTION - CORRECTION OF HYPEROPIA

	original mean anterior corneal radius					
y	6.000	7.000	8.000	9.000	10.000	11.000
3.0	6.826	7.257	7.534	7.718	7.841	7.945
3.5	4.565	5.008	5.289	5.470	5.604	5.726
4.0	3.083	3.546	3.830	4.021	4.158	4.254

CENTER REDUCTION - CORRECTION OF MYOPIA

	original mean anterior corneal radius					
y	6.000	7.000	8.000	9.000	10.000	11.000
3.0	7.406	7.720	7.910	8.036	8.129	8.153
3.5	5.058	5.401	5.620	5.755	5.848	5.890
4.0	3.525	3.890	4.113	4.261	4.363	4.435

table Nº 2. This would mean that a 0.1 mm. reduction in center thickness would cause a change in vertex power of 7.406 diopters. If this c value of 0.1 mm. is divided by the ametropia of -7.406 diopters, the resultant amount is .0135. Therefore the relationship of c/a may be calculated by determining the reciprocal of each of the values in table Nº 2. The c/a values are listed in table Nº 3. These values may be plotted in graph form. Figure Nº 6 is the graph containing the information in table Nº 3. The graph may be utilized for smaller increments of radius than those used for the calculations. The ordinate is the K reading in millimeters of radius and the abcissa is the c/a value.

The graph may be applied in the following manner: The appropriate y value is selected, based on considerations that will be described in a later section of this discussion. The mean corneal radius is found on the graph, and the intersection of this line with the curve on the graph is the c/a value. Once the c/a value is determined, it is multiplied by the ametropia to arrive at c, since c/a . a = c. This is the method used to determine the degree of ametropia.

Example Nº 4: K reading: -2.50 cylinder axis 180, axis meridian 42.00. 5.00 diopters myopia.

mean corneel radius : 7.80

y value : 3 mm.

c/a (from graph) : 0.01271

c/a · a = c : 0.06355

Therefore, in this hypothetical situation, there would be a reduction of 0.06355 mm. in the central thickness in a carved zone of 6 mm. in diameter in order to achieve a correction of the myopia.

All this reasoning has be predicated upon carving the anterior surface of the cornea. This approach, from a surgical standpoint, is unwise, since it would involve the carving of Bowmans membrane. It is necessary to carve the posterior surface of the corneal disc. This brings to the fore the mathematical danger of reducing center thickness without taking the radius of carving into consideration. If the appropriate change in center thickness is carved in the posterior surface and the corneal section is later bent to the curvature of the bed before suturing. the vertex power of the section will change as a consequence of bending [5]. Therefore, the corneal section must be frozen in opposition to the concave lap so that the anterior surface will assume the final curvature desired after it is placed in the bed. Now, if the front curvature will match the final curvature desired, so will the posterior curvature, after carving to match the curvature of the bed.

TABLE III

c/a Values

EDGE REDUCTION - CORRECTION OF HYPEROPIA

y	original mean anterior corneal radius					
	6.0	7.0	8.0	9.0	10.0	11.0
3.0	0.01465	0.01378	0.01327	0.01296	0.01275	0.01259
3.5	0.02191	0.01997	0.01891	0.01830	0.01784	0.01746
4.0	0.03244	0.02820	0.02611	0.02487	0.02405	0.02351

CENTER REDUCTION - CORRECTION OF MYOPIA

y	original mean anterior corneal radius					
	6.0	7.0	8.0	9.0	10.0	11.0
3.0	0.01350	0.01295	0.01264	0.01244	0.01230	0.01227
3.5	0.01997	0.01853	0.01779	0.01738	0.01710	0.01698
4.0	0.02759	0.02571	0.02431	0.02347	0.02292	0.02255

TABLE IV

Theoretical Limits of Dioptric Change by Carving
Edge Reduction - Correction of Hyperopia

y	*original mean anterior corneal radius*					
	6.000	7.000	8.000	9.000	10.000	11.000
3.	19.113	20.320	21.095	21.610	21.955	22.246
3.5	12.782	14.022	14.809	15.316	15.691	16.033
4.0	8.632	9.929	10.724	11.259	11.642	11.911

CENTER REDUCTION - CORRECTION OF MYOPIA

y	*original mean anterior corneal radius*					
	6.000	7.000	8.000	9.000	10.000	11.000
3.0	20.737	21.616	22.148	22.501	22.761	22.828
3.5	14.162	15.123	15.736	16.114	16.374	16.492
4.0	9.870	10.892	11.516	11.931	12.216	12.418

The curvature of the bed is known. It is calculated simply by subtracting the thickness of the corneal disc from the mean anterior corneal radius.

Example Nº 5: mean anterior corneal radius: 7.80 mm., thickness of corneal section: 0.4 mm., mean radius of bed 7.80 — 0.40 = 7.40 mm.

If the anterior surface of the cornea, therefore, were bent to a concave lap precalculated in radius to be the desired radius after surgery, it is then merely necessary to carve the corneal bed radius into the posterior surface of the corneal slice.

It is now incumbent to determine the new anterior corneal radius. This may be performed in the following manner:

1. determine the sagitta of the original mean anterior corneal radius (by the application of formula (9) or consulting tables).

2. subtract the c value as previously determined in myopia, or add the c value as previously determined in hyperopia; this result is the sagitta for the new anterior corneal radius (the application of formula (8) or (15)), and

3. determine the new anterior corneal radius from the data of the sagitta and the y value (by the application of formula (1) or consulting tables).

There are sagitta tables computed expressly for this purpose. Barraquer [6] has published a series but the most comprehensive tables are by Creighton [7]. The utilization of Creighton's tables enables one to easily translate radius to the corresponding sagitta, given a y value, and vice versa.

OPTICAL LIMITS

It would be interesting to determine the theoretical limits of dioptric change by carving. This may be performed by consulting table Nº 4. The first figure that appears on the table may be used as an illustration.

Example Nº 6: for a cornea with a mean anterior radius of 6.00 m., and for a preselected y value of 3.0 mm., it may be seen that a 0.1 mm. reduction in edge thickness would yield a change of 6.826 diopters. This edge thickness change would be desired in the correction of hyperopia. Since the maximum degree of thickness change dictated by surgical considerations is 0.28 mm., the multiplication of 2.8 by the degree of change wrought by 0.1 mm., reduction in thickness would yield the maximum dioptric change possible. It may be seen, therefore, that in the example as described, the maximum change possible with an original mean corneal radius of 6.00 mm. and a y value of 3.0 mm. is 19.113 diopters.

Inspection of table Nº 4 will reveal that the smaller the y value, the greater the maximum change possible. Also, the flatter the original mean anterior corneal radius, the greater the degree of maximum change possible. Also, assuming the same y value and the same original anterior corneal radius, it may be seen that the maximum change possible is greater in myopia correction than is hyperopia correction.

SELECTION OF THE APPROPRIATE "y"

Selection of the appropriate y value has been cursorily mentioned but passed over. It is now germaine to discuss the considerations that inter into the selection of the appropriate y value. The two main factors to be evaluated are the original ametropia of the eye, and the thickness of the corneal disc after carving. It has also been mentioned that surgical considerations dictate that the minimum remaining corneal disc thickness should not be less than 0.12 mm. The maximum permissable c value, therefore, must be 0.28 mm., assuming an original corneal disc thickness of 0.4 mm. If the original corneal disc thickness is greater or less than 0.4 mm., the value of 0.12 mm. is merely deducted from this to arrive at the maximum permissable c value (this being the reduction in center or edge thickness necessary to achieve the desired results).

Table Nº 4 reveals that the original mean anterior corneal radius and the y value are the factors that limit the maximum change in the correction of the ametropia. If a larger y value is chosen, the accuracy of the carving will be greater. However, if the desired correction cannot be achieved with this larger y value, a smaller one must be chosen. Table Nº 4, therefore, must be examined in order to compare the ametropia and the original mean anterior corneal radius maximum change possible with the ametropia in the particular case under consideration. If the maximum change possible is less than the ametropia to be corrected using a larger y value, it is then necessary to select the next smaller y value in order to achieve the desired change.

CONCLUSION

Any method of calculation that envisages lathe-carving the corneal section followed by bending the carved section to a different curvature must, of necessity, take in to consideration the consequences of dioptric change as a result of bending. The degree of this change is not accurately predictable. It is submitted, therefore, that the most accurate approach in the solution of this problem is one where the corneal section is bent before carving, so that the anterior surface will conform to its desired new curvature. This will allow the lathe-carving of the posterior surface to a curvature matching that of the bed, so that no further bending will take place after carving. The pitfall of dioptric change as a consequence of bending will then be avoided.

SUMMARY

The best summary of the steps necessary in the calculation of the parameters necessary in the calculation of the parameters for lathe carving the corneal disc in refractive keratoplasty may be had by referring to figure Nº 7. This is a form used by the Katzin group in the biological experimentation phase of their refractive keratoplasty research. The appropriate lap may then be chosen and the lathe correctily set to carve the frozen corneal section so that the desired result will be achieved.

ABSTRACT

Refractive keratoplasty is a form of surgical intervention which has been devised to alter the cornea so as to eliminate ametropia.

The eye is fixed with a pneumatic ring through which passes a microkeratome. This instrument, which operates on the principle of a carpenter's plane, shaves a corneal disc from the eye. The disc is then carved a replaced on its bed.

This paper contains some introductory background, relating to technique, but is principally devoted to the formulation of change by lathe-carving the corneal tissue disc. The anterior surface of the corneal disc is frozen to a concave lap, precalculated to match the desired new anterior radius of the cornea. The posterior surface is carved to match the radius of the corneal bed. The optical considerations and calculations for this method are explained.

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