United States Patent [19]

England

[11] **3,861,089**

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[54] **METHOD OF MAKING CONTACT LENS**

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[52] **U.S. Cl.** **51/284,** 51/324

[51] **Int. Cl.** **B24b 13/02**

[58] **Field of Search** 51/284, 324

[56] **References Cited**

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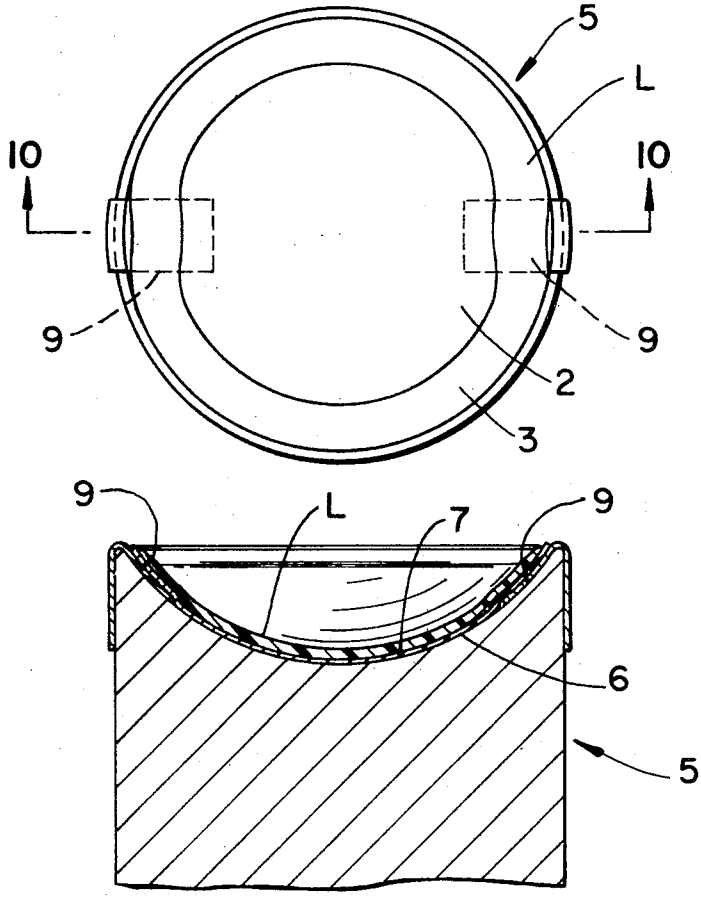
Primary Examiner—Donald G. Kelly

Attorney, Agent, or Firm—John Harrow Leonard

[57] **ABSTRACT**

An uncut contact lens of resilient, self-restoring plastic material having a central or base spherical curve is ground to provide a surrounding annular spherical peripheral curve of greater radius of curvature than the base curve. The lens is finish ground for a particular cornea by first warping a preselected diametral axis so that the projection of the periphery of the curve on a plane normal to the visual axis of the lens is elliptical. While the lens is maintained in this warped condition, a spherical grinding tool of selected diameter is applied coaxially with the visual axis so as to grind the peripheral curve, whereby material is removed to a greater depth and width from the peripheral curve at the ends of the minor axis of the ellipse, and progressively less is removed from the peripheral curve in a direction away from the minor axis and toward the major axis. Upon completion of the grinding, the lens is released and self-restores to its unwarped condition, in which condition the peripheral curve becomes toric.

8 Claims, 20 Drawing Figures



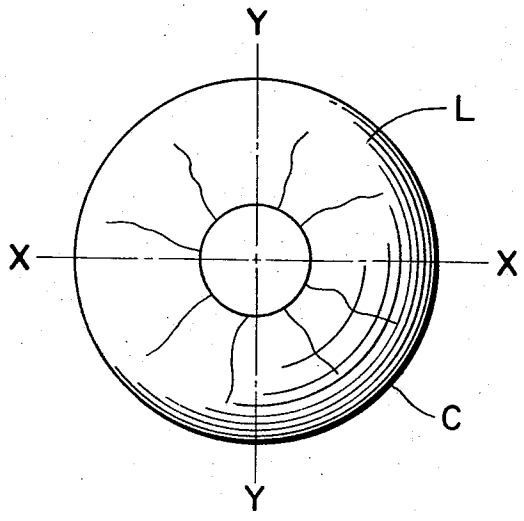


FIG. 1
PRIOR ART

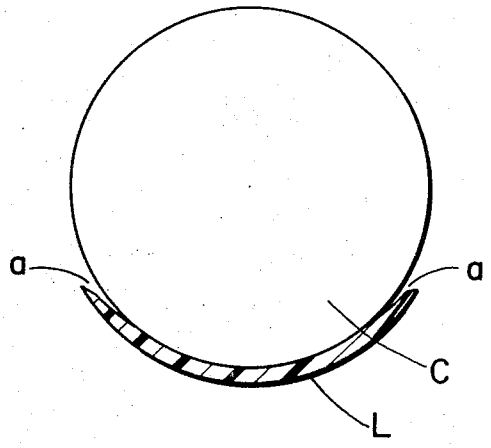


FIG. 2
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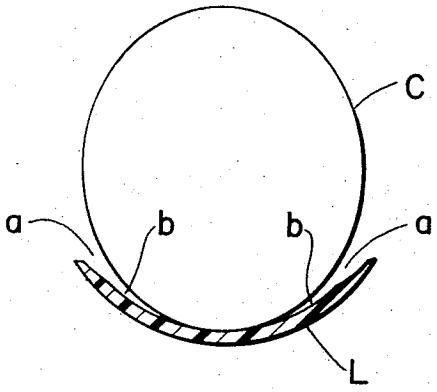


FIG. 3
PRIOR ART

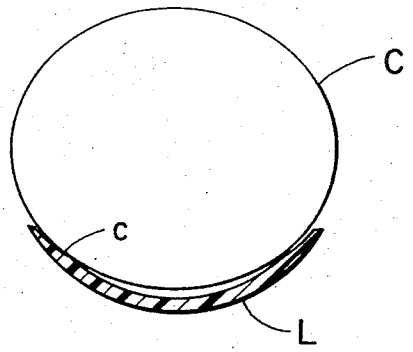


FIG. 4 PRIOR ART

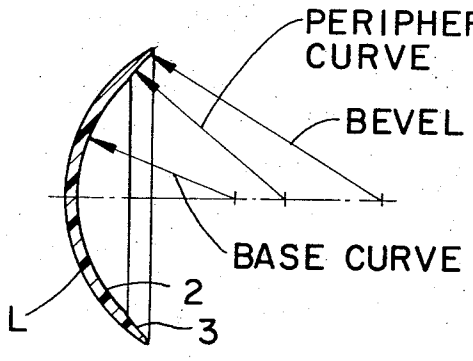


FIG. 6
PRIOR ART

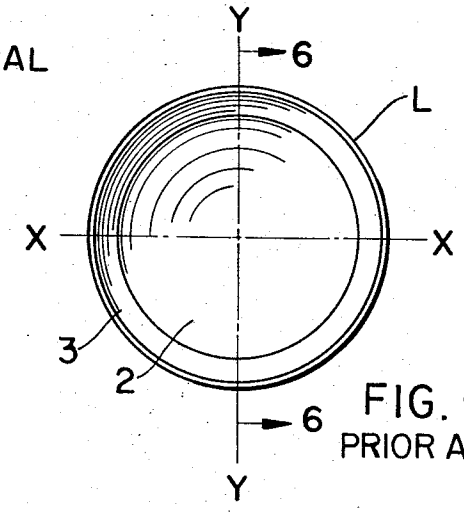


FIG. 5
PRIOR ART

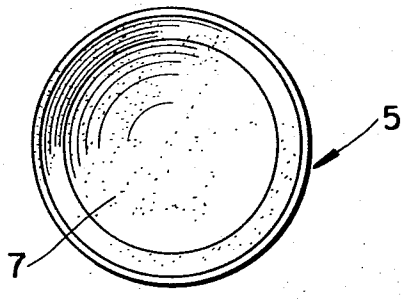


FIG. 7
PRIOR ART

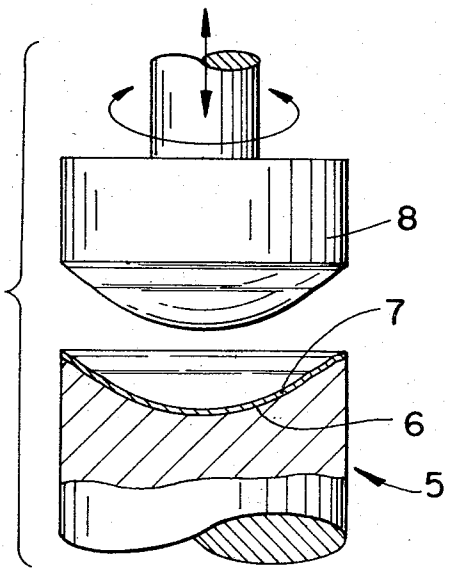
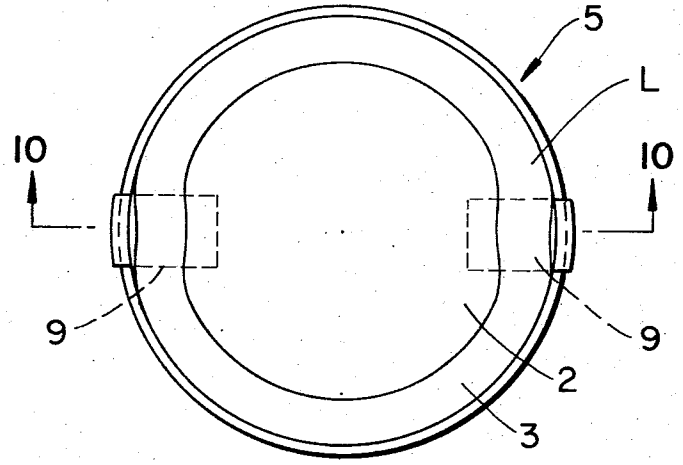


FIG. 8
PRIOR ART

FIG. 9



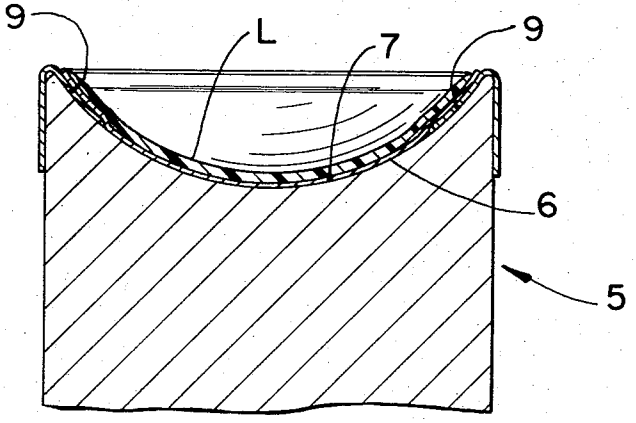


FIG. 10

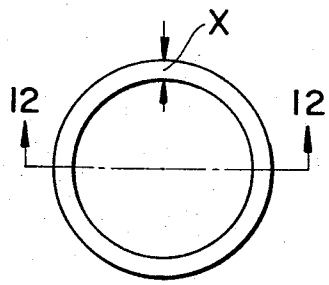


FIG. 11
PRIOR ART



FIG. 12
PRIOR ART

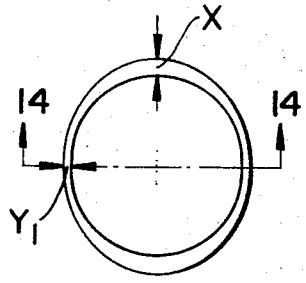


FIG. 13



FIG. 14

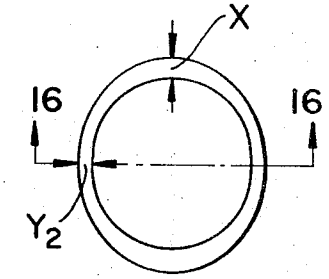


FIG. 15



FIG. 16

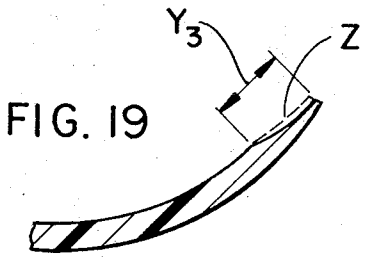


FIG. 19

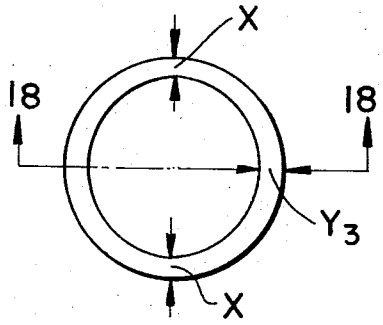


FIG. 17

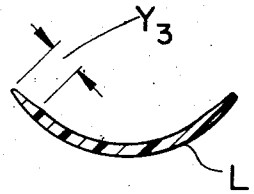


FIG. 18

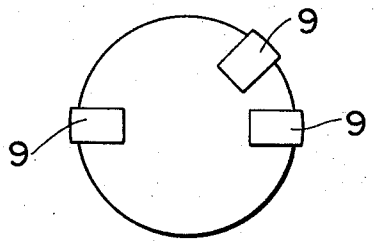


FIG. 20

METHOD OF MAKING CONTACT LENS

BACKGROUND OF INVENTION

1. Field of Invention

Contact lenses.

2. Description of Prior Art

Heretofore contact lenses generally have been formed with a forward face ground to the various curvature required to produce the refractive power prescribed by the practitioner and with the rear face having a central or base curve which is generally spherical surrounded by a marginal or peripheral annular curve which is also spherical and which has a longer radius of curvature than the base curve. For example, a lens may be 9 mm. in outside diameter with its rear face having a base curve of spherical form and about 7 mm. in outside diameter with a radius of curvature of 7½ mm., surrounded by an annular peripheral curve which is spherical and about 1 mm. in annular width with a radius of curvature of about 8½ mm. These radii, of course, may be varied as required.

The lenses in this condition are sent to the practitioner for dispensing. However, some lenses in this condition do not properly fit the cornea of the patient's eye. This is because the radius of curvature of the cornea usually is not constant, most corneas being toric to various degrees in various meridians about the visual axis, instead of spherical. The radius of curvature of the central portion of the cornea can be measured easily with a relatively high degree of precision, using an instrument called an ophthalmometer. The varying curvature of the peripheral portion of the cornea can be closely approximated by an experienced practitioner. Using the data obtained from these measurements and approximations, the practice has been to grind the rear face of the spherical base curve and the spherical peripheral curve to fit the particular eye. However, "fitting" does not mean that the shape of the rear face of the lens is to conform with the portion of the cornea which it is to overlie. On the contrary, it must not match precisely the periphery of the cornea which it is to overlie as such would prevent the proper flow of tear fluid beneath the lens. Further, it would tend to hold the lens in coaxial relation with the axis of the cornea, whereas it is necessary that the lens wobble slightly transversely of its axis and thereby perform a limited pumping effect which insures the proper flow of tear fluid over that portion of the cornea overlain by the lens. If this wobble effect were not provided, the resultant stationary condition of a close fitting lens would entrap tear fluid between the lens and cornea. The entrapped fluid would tend to stagnate and thus deprive the cornea of oxygen which it customarily derives from the tear fluid, because the cornea does not have any capillaries enabling it to derive its oxygen supply from the blood. The tear fluid or solution transports an appreciable amount of atmospheric oxygen now known necessary for corneal respiration; for example, about 10% oxygen when the person is in good health.

There are other disadvantages in lenses in which the rear face of the peripheral curve is spherical. Among these are the following:

When placed on a highly toric cornea there is often too much clearance or "stand-off" from the underlying portion of the cornea at all or some meridians, and perhaps insufficient stand-off or clearance at other meridians. Generally, this excess of clearance would be at meridians 180° apart, and any deficiency of clearance would be at meridians spaced 90° therefrom. Such a fit is improper and inconsistent with the optimum comfort and functioning. Further, the spherical shape does not permit the lens to wobble uniformly and to a limited amount about its axis, but rather to rock excessively about one diameter and to prevent it from rocking about another diameter 90° therefrom. Again, if the lens migrates off center, it may be constrained from sufficient rocking even in the permitted direction.

On the other hand, with the non-toric cornea, one in which the central portion is substantially spherical, the fit is also improper. The contact line of the peripheral curve of such a lens with non-toric cornea defines a plane normal to the commong axis of the base curve and of the cornea, thus is in the form of a true circle. Such a fit, however, prevents any appreciable wobble of the lens so that the space between the cornea on the one hand, and the base curve and the peripheral curve on the other, is, in effect, a cul-de-sac in which the tear fluid remains entrapped and stagnates. This not only deprives the cornea of the necessary oxygen, as memtioned, but also causes discomfort to the patient. The fit is too close a match for comfort and proper functioning.

In accordance with prior practices attempts are made to approximate roughly a toric peripheral curve by applying a spherical grinding tool to the peripheral curve on the rear face of a lens while the lens is held with its visual axis at an angle of the axis of the rotating grinding tool. This reshapes a portion of the peripheral curve of the lens at one side of the lens visual axis. The operation is repeated at the opposite side of the rear face, a location 180° removed from the curve produced by the first grinding. As a result the rear face of the lens has three non-coaxial peripheral curve surfaces, none of which is toric. The resultant lens has discernible ridges or sharp lines of demarcation at those locations where the ends of each reground portion of the peripheral curve intersect the adjacent ends of the original peripheral curve. This method of grinding uneven or variant peripheral curves has proven to be unsatisfactory and has not achieved much popularity. It is, at best, an attempt to produce a very rough approximation of true toricity.

The present invention is directed to providing on the rear face of a lens having a toric or non-toric base curve, a toric peripheral curve, as distinguished from a spherical peripheral curve. For this purpose, as in the prior art, the forward face is ground to provide the prescription specified by the practitioner, and the rear face is ground to provide a base curve according to the prescription of the practitioner for the central portion of the prescriptition particular cornea. At this point, divergence of the present invention from prior practice is introduced and results in a method which overcomes the disadvantages hereinbefore discussed. The new method results in the proper fitting so that the lens can wobble sufficiently to assure an adequate flow of tear fluid between its under face and the face of the cornea which it overlies, provides a lens which will maintain its proper position on the surface of the cornea, and on which is free from abrupt changes in curvature in the peripheral curve, lines of demarcation, and the like on the rear face of the toric peripheral curve, all of which can cause distress to the patient or become uncomfortable either to the eye itself or to the eye lid.

If the base curve is toric, then the toric peripheral curve generally is ground so that the minor axis of the projection of the base curve and peripheral curve are coincident. In some instances, when prescription is such that it is desirable to dispose the minor axes at any preselected angle to each other, such may be done in the practice of the invention.

The various steps of the present method and the manner in which they can be readily effected will become apparent from the following description of a preferred embodiment of the invention wherein reference is made to the drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. **1** is a diagrammatic front elevation of a cornea which is toric, having one radius of curvature, along one meridian and a different radius of curvature along the meridian at right angles to said one meridian;

FIG. **2** is a diagrammatic cross sectional view showing the fitting of a contact lens with a spherical peripheral curve along the meridian *x—x* of the cornea of FIG. **1**;

FIG. **3** is a diagrammatic cross sectional view showing the misfitting of a lens with a spherical peripheral curve along the meridian *x—x* of the cornea in FIG. **1**;

FIG. **4** is a diagrammatic illustration of another misfit of a contact lens with a spherical peripheral curve along the meridian *y—y* of the cornea of FIG. **1**;

FIG. **5** is a plan view of the rear face of a conventionally ground lens to be finished in accordance with the present invention;

FIG. **6** is a cross sectional view of the lens illustrated in FIG. **5**, and is taken on the line **6—6** thereof;

FIG. **7** is a top plan view of a tool for holding the lens for grinding;

FIG. **8** is a front elevation of the instrument illustrated in FIG. **7**, with a rotary reciprocable grinder in coaxial relation and in retracted position with the tool of FIG. **7**;

FIG. **9** is an enlarged diagrammatic top plan view of the tool of FIG. **7** with a lens mounted therein in position for grinding in accordance with the present invention;

FIG. **10** is a diagrammatic cross sectional view taken on the line **10—10** in FIG. **9**;

FIG. **11** is a diagrammatic top plan view of the rear face of a lens with a spherical base curve and spherical peripheral curve preparatory to being subjected to the present method;

FIG. **12** is a cross sectional view taken on the line **12—12** of FIG. **11**;

FIG. **13** is a diagrammatic view of the rear face of the lens illustrated in FIG. **11** in the warped condition in which the lens is mounted for grinding in accordance with the present invention;

FIG. **14** is a cross sectional view taken on the line **14—14** of FIG. **13**;

FIG. **15** is a view similar to FIG. **13** showing the lens in the warped condition after grinding;

FIG. **16** is a cross sectional view taken on the line **16—16** of FIG. **15**;

FIG. **17** is a rear view of the lens after grinding, but self-restored to its original unwarped condition;

FIG. **18** is a cross sectional view taken on the line **18—18** of FIG. **17**;

FIG. **19** is an enlarged fragmentary sectional view of the right hand portion of the lens illustrated in FIG. **18**, showing the removal of material from the peripheral curve at one side of the visual axis of the lens;

FIG. **20** is a view similar to FIG. **9** but illustrating the method of warping the lens relative to more than one transverse axis preparatory to grinding.

DESCRIPTION OF A PREFERRED EMBODIMENT OF THE INVENTION

Referring first to FIGS. **1–4**, as generally discussed hereinbefore, the usual cornea is not spherical, but somewhat toric in one or more meridians. The cornea C shown in FIG. **1** is assumed first to be spherical. Assuming that a spherical lens L with a base curve of the same radius of curvature as the cornea C is applied to the cornea C, it is seen, as illustrated in FIG. **2**, that the base curve of the lens L engages the entire underlying surface of the cornea C. The peripheral curve being of longer radius of curvature from the base curve, has clearance relative to, or "stand out" slightly from, the cornea, as indicated at *a*. Such a relation does not permit the lens to wobble about its visual axis, and does not restrain the lens from lateral migration from its proper position. In fact, migration, in such an instance, presents a considerable problem.

Assuming the radius curvature of the cornea C along the meridian *x—x* of the cornea in FIG. **1** is substantially less than the base curve of the lens L, then, as illustrated in FIG. **3**, the lens L rests on the cornea C at the central portion of the cornea, but the peripheral curve of the lens L stands out too far from the cornea at the meridian *x—x*, as indicated at *a*, as also does the outer portion of the base curve, as indicated at *b*. This excessive clearance permits the lens to wobble inordinately beyond normal and is discomforting to the wearer.

On the other hand, as indicated in FIG. **4**, if the abnormal curvature of the cornea along the meridian *x—x* is very pronounced, but the radii of curvature of the base curve of the lens L and of the cornea C along the meridian *x—x* are such as to provide a proper fit, and the radius of curvature of the cornea along the meridian *y—y* is much greater, so that the curvature along the meridian *y—y* is slight, the peripheral curve of the base curve of the lens L either engages the cornea at the meridian *y—y*, as indicated at *c* in FIG. **4**, or has too small a clearance.

In all instances, the relative fit or misfit at a given meridian extends toward and merges gradually with the fit or misfit at the meridian at 90° thereto.

None of these relations is satisfactory and the problem is to combine with a properly fitting base curve, as heretofore produced, a properly shaped toric peripheral curve, so that the peripheral curve is properly spaced from the cornea throughout its extent to assure the necessary rocking or pumping action, to resist turning of the lens about its visual axis, to restrain migration of the lens laterally or edgewise from its proper position relative to the central portion of the cornea, to prevent irritation of the eyelid or the cornea, and to prevent air bubbles from forming under the peripheral portion of the lens, which bubbles tend to migrate between the cornea and base curve of the lens and interfere with vision.

Referring to FIGS. **5–18**, the present method is illustrated as applied to a lens L of resilient, self-restoring plastic of good memory, such, for example, as polymethylmethacrylate. The lens L has a forward face

ground in accordance with the prescription found by the practitioner to be necessary for proper vision, and has a rear face with a central or base curve **2** which is ground in accordance with the specifications of the practitioner for a proper fit along the central portion of a toric cornea. The base curve **2** is surrounded by a peripheral curve **3** which is similar and marginal, and which, in the state of the lens as illustrated in FIG. **5,** is of constant width, spherical, and of longer radius of curvature than the base curve **2.** The lens is usually bevelled slightly at the outer edge, as illustrated.

As an example of a typical contact lens, the lens shown has a base curve with a radius of curvature of 7½ mm. and a spherical peripheral curve of radius of 8½ mm. Generally, the diameter of the base curve is about 7 mm. and the outer diameter of the annular peripheral curve is about 9 mm.

These plastic lenses cannot be fitted properly by heating, warping, or cooling. Instead, starting with the lens thus prepared for the particular eye, and having a spherical peripheral curve, the lens, at room temperature, is supported in a conventional jig or holder **5** which has a central cavity **6** which is relatively shallow and spherical. Ordinarily, the lens is held in the cavity **6,** with its forward side facing toward the bottom of the cavity, by means of adhesive, such as double faced adhesive tape **7** of the pressure sensitive type. In accordance with prior practices, the lens, while so held, is ground with a spherical grinder **8** applied to the spherical peripheral curve. The lens is manipulated manually to obtain the reshaping of the peripheral curve to a very rough approximation of a toric curvature. However, the curvatures at different portions of the peripheral lens remain spherical, being merely defined by spherical portions of different diameters, as hereinbefore mentioned.

In accordance with the present invention, the lens L is mounted in a like holder **5** and while so mounted is warped transversely about one diametral axis. This warping is effected by suitable shims **9** which are introduced between the lens L and holder **5,** at opposite ends of the same meridian of the lens so as to temporarily bend and warp the lens upwardly and inwardly at the locations of the shims **9,** thus causing the projection of the outer periphery of the lens onto a plane normal to the visual axis of the lens to assume an elliptical shape with the minor axis extending in a direction from one shim to the other.

Preferably the shims **9** are small pieces of thin tape with adhesive on one face. They are disposed with the adhesive facing toward the wall of the cavity **6** and pressed in place so as to be held adhesively in the proper position in the cavity. The outer ends of the pieces are lapped over the outer side wall of the tool to assure that they remain properly in place. If desired, a single strip extending entirely across the cavity diametrally may be used for the shims **9.** A small thin disc of the double faced adhesive tape **7,** with pressure sensitive adhesive, is placed in the cavity in overlying relation to the shims **9** and the lens is superposed thereon and pressed downwardly into the cavity. The shims **9** cause the lens to be warped so that its outline, as projected on a plane normal to its visual axis, is elliptical with its minor axis extending along the line between the two shims **9.** The disc of adhesive tape **7** holds the lens in warped condition.

As indicated in FIG. **11,** in the starting lens, the radial width of the peripheral curve, indicated at x, is constant. In FIG. **13,** the width of the projection of the peripheral curve on a plane normal to the visual axis appears narrower at the ends of the minor axis, as indicated at y, than at x, because the curve at and adjacent y, is tilted relative to such a plane.

While the lens is held in this condition, a spherical grinder **8** of preselected radius, and with its axis generally coaxial with that of the visual axis of the lens, is applied to the peripheral curve. Since the projection of the peripheral curve is in elliptical form while the curve is being subjected to the spherical grinder, more plastic is removed along the peripheral curve at the ends of the minor axis than is removed from the peripheral curve at the ends of the major axis. The depth and width of removal of material by the grinder both are decrescent by minute increments from the ends of the minor axis toward, and sometimes to, the major axis. The gradation is such that there are no ridges or sharp lines of demarcation on the surface of the peripheral curve. Instead, there is a gradual transition from the maximum ground area at the ends of the minor axis to the minimum ground area at or near the ends of the major axis.

In FIG. **15,** the lens L is shown in warped condition with the peripheral curve ground. The peripheral curve has essentially the original radial width x at the ends of the major axis, but is widened somewhat, as indicated at $y2$, compared to y_1 of FIG. **13,** because some of the material has been ground away at the ends of the minor axis. As mentioned, the width and depth of the removal, due to the warped condition during grinding, decreases incrementally progressive from the ends of the minor axis toward, or to, the ends of the major axis.

Having thus ground the lens, it is removed from the holder, and self-restores to its unwarped condition, in which condition the peripheral curve is toric. The edges are then bevelled and polished to smoothness.

When the lens is released and self-restores to its unwarped condition, as illustrated in FIG. **17,** the peripheral curve is seen to be toric, being then more deeply than originally, at the ends of the minor axis, as indicated at $y3$ with the depth of grind gradually fading out toward the ends of the major axis. The peripheral curve thus becomes toric, and free from any sharp ridges of demarcation between its various areas. The original surface of the peripheral curve at the ends of the minor axis is indicated by the dotted line z.

The axis about which the lens is warped and the degree of peripheral curve toricity desired by the practitioner who prescribes the lens, are dictated by the size and toricity of the portion of the cornea which the lens is to overlie, allowance being made in the lens for proper contact and proper clearance for stand-out.

In some unusual cases, more than two shims may be used to control the warpage of the lens preparatory to grinding its peripheral curve with the spherical grinder. By using three or more shims **9,** as indicated in FIG. **20,** the lens can be warped properly so that the toric peripheral curve fits properly on a toric cornea of which the toricity is not uniform, but instead varies irregularly from one meridian to another. The shims **9** are positioned at asymmetrical locations where substantial removal of material and reshaping of the toric peripheral curve are to be effected by the grinding operation.

The fit in all cases is such that the peripheral curve has the proper limited clearance or stand-out with re-

spect to the under-lying cornea, — close enough to prevent undue rocking of the lens about its visual axis, migration of the lens edgewise and relative to the visual axis of the cornea, and rotation of the lens about its visual axis. The lens fits without discomfort to the cornea or the eyelid.

Having thus described my invention, I claim:

1. The method of grinding a contact lens of resilient self-restoring material and having front and rear faces, respectively, and having on its rear face a base curve of prescribed configuration surrounded by a peripheral annular curve which is generally spherical and which has a radius of curvature longer than the radius of curvature of the base curve, and of which the outermost peripheral edge of the peripheral annular curve is substantially circular, comprising:

warping one or more areas of the peripheral curve portion of the lens into a condition in which the shape of the projection of the outermost peripheral edge of the peripheral curve on a plane perpendicular to the axis of the lens is out-of-round, by the application to one or more areas of the front face of the lens, which areas are aligned axially of the lens with the peripheral curve, of extraneous forces directed generally perpendicular to said front face at their points of application, while leaving the entire peripheral edge of the lens unconstrained radially of the lens axis;

securing the lens fixedly in said warped condition;

then, while the lens is held firmly in said warped condition, applying a rotary spherical faced grinding tool to said rear face of the lens only on said peripheral curve with the rotary axis of the tool in substantially coaxial relation to the visual axis of the lens and, while leaving the base curve intact, grinding only the peripheral curve to a predetermined degree such that the warped portion of the peripheral curve is spherical in the warped condition and the lens material is removed from the peripheral curve to the greatest width and depth at the shortest radius of said projection and such that the width and depth of removal of material at the different circumferential portions of the peripheral curve is inversely proportional to the length of their radii, respectively; and

then releasing the lens and permitting it to selfrestore to its original unwarped condition; whereby the base curve retains its prescribed contour and the peripheral curve is torically contoured.

2. The method according to claim **1** wherein the lens is warped by mounting it in a concavity in a holder, which concavity is circular in sections normal to its axis, with the front face of the lens facing the bottom of the concavity and adhesively secured to the cavity wall, so that the major portion of the front face of the lens, aligned with the peripheral curve, is held adhesively in substantial conformance with the contour of the wall of the concavity, and said one or more areas, by said application of extraneous forces, are held warped away from said wall of the concavity and inwardly away from the rim of said concavity.

3. The method according to claim **1** wherein said forces, are applied at a plurality of areas which are spaced apart from each other circumferentially of the visual axis of the lens.

4. The method according to claim **3** wherein said forces are applied at at least three areas about the periphery.

5. the method according to claim **2** wherein the extraneous forces are applied by inserting a shim or shims between the peripheral portion of the lens and the wall of the holder concavity at said areas.

6. The method according to claim **3** wherein said forces are applied at least at two areas which are diametrically opposite from each other.

7. The method according to claim **3** wherein said forces are applied at least two areas which are out of diametral alignment with each other.

8. The method according to claim **6** wherein the forces are applied at at least one additional area which is asymmetrically arranged relative to said diametrically opposite areas.

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