

HYDROLIC ACCOMMODATING INTRAOCULAR LENS

BACKGROUND

[0001] Intraocular lenses have for many years had a design of a single optic with loops attached to the optic to center the lens and fixate it in the empty capsular bag of the human lens. In the mid '80s plate lenses were introduced, which comprised a silicone lens, 10.5 mm in length, with a 6 mm optic. These lenses could be folded but did not fixate well in the capsular bag, but resided in pockets between the anterior and posterior capsules. The first foldable lenses were all made of silicone. In the mid 1990s an acrylic material was introduced as the optic of lenses. The acrylic lens comprised a biconvex optic with a straight edge into which were inserted loops to center the lens in the eye and fixate it within the capsular bag.

[0002] Recently accommodating intraocular lenses have been introduced to the market, which generally are modified plate haptic lenses and, like the silicone plate haptic lenses, have no clear demarcation between the junction of the plate with the optic's posterior surface. A plate haptic lens may be referred to as an intraocular lens having two or more plate haptics joined to the optic.

[0003] Flexible acrylic material has gained significant popularity among ophthalmic surgeons. In 2003 more than 50% of the intraocular lenses implanted had acrylic optics. Hydrogel and collamer lenses have also been introduced.

[0004] The advent of an accommodating lens which functions by moving along the axis of the eye by repeated flexions somewhat limited the materials from which the lens could be made. Silicone is the ideal material, since it is flexible and can be bent probably several million times without showing any damage. Additionally a groove or hinge can be placed across the plate adjacent to the optic as part of the lens design to facilitate movement of the optic relative to the outer ends of the haptics. On the other hand, some acrylic materials can fracture if they are repeatedly flexed.

[0005] An example accommodating lens is a type as disclosed in U.S. Patent No. 6,387,126 and others in the name of J. Stuart Cumming.

SUMMARY OF THE INVENTION

[0006] According to a preferred embodiment of this invention, an accommodating lens comprises a lens with a flexible solid and interior liquid optic, preferably with two or more extended portions from the solid optic which may be plate haptics capable of multiple flexions without breaking, preferably along with fixation and centration features at their distal ends. There may be a hinge or groove across the extended portions adjacent to the optic to facilitate the anterior and posterior movement of the optic relative to the outer ends of the extended

portions. On the other hand, the optic may be rigidly attached to the haptics. Also, haptics can be omitted.

[0007] According to the present invention the optic is of a foldable, flexible silicone, acrylic, collamer or hydrogel material with an interior of liquid silicone, or other optically clear fluid, and the haptics are of a foldable material that will withstand multiple foldings without damage, e.g., silicone. Preferably, the end of the plate haptics have T-shaped fixation devices and the haptics are hinged to the optic.

[0008] The lens of the present invention is made of solid silicone with liquid silicone both of which may have similar or the same refractive indices. The liquid may be any other liquid that is optically clear and has a different refractive index than the solid silicone. It is preferable that the liquid in the optic have a specific gravity the same as or very similar to that of the aqueous solution of the natural eye. The power of the lens can be changed by (1) changing the radius of the solid central posterior portion of the optic, and/or (2) by changing the volume of the liquid silicone in the lens optic, or (3) by changing the refractive index of the liquid either before or after implantation. The posterior surface of the lens is pushed forward by vitreous cavity pressure with constriction of the ciliary muscle. This causes bulging of an anterior membrane of the lens increasing its curvature and thus decreasing the radius of the anterior surface of the lens increasing the lens power for near vision.

[0009] The thin anterior membrane may be thicker in its periphery such that an increase in pressure inside the lens will produce a central bulging of the membrane. This structure simulates the structure of the anterior capsule of the human lens and simulates its function. The posterior central optic portion may have additional single or multiple solid spherical components or may be aspherical or toric on its posterior surface. Also, the increase in vitreous cavity pressure can tilt the lens to further facilitate accommodation.

[0010] Accordingly, features of the present invention are to provide an improved form of accommodating lens formed from solid and liquid silicone.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] Fig. 1 is a side cross sectional view of the preferred embodiment of the lens of the present invention.

[0012] Fig. 2 is a plan view from the anterior side of the lens.

[0013] Fig. 3 is a plan view from the posterior side of the lens.

[0014] Fig. 4 is a cross-sectional view of the lens like Fig. 1 but showing bulging or increased curvature of an anterior portion of the lens.

[0015] Figs. 5 and 6 are variations in cross section.

[0016] Figs. 7-8 illustrate further variations.

[0017] Figs. 9-12 illustrate different forms of haptics that can be used on lenses of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

[0018] Turning now to the drawings, a preferred embodiment is shown in detail, comprising an intraocular lens with an optic 10 and haptic 16. The optic 10 is formed of two components, namely, a flexible solid portion 12 (12a – 12d) preferably made of silicone, collamer, acrylic or hydrogel, and an interior liquid preferably silicone portion 14. The portions 12a and 12b are sufficiently solid to prevent deformation of the optic 10 upon implantation into the fibrosed capsular bag of the eye. The flexible extending portions 16 may be plate haptics which are capable of multiple flexations without damage, and formed, for example, of silicone. The optic 10 and haptics 16 preferably are uniplanar, and two or more haptics 16 extend distally from opposite sides of the optic 10. The outer ends of the haptics 16 may include flexible fingers 17 such as disclosed in US Patent No. 6,387,126 to Cumming. Preferably the edge 24 of the optic is a 360° square edge.

[0019] The lens 10 includes portions 12a, 12b and 12d of solid silicone and wherein the portion 12c is substantially thinner, and 12d is even thinner than 12c, to enable a degree of flexibility as can be seen in comparing Fig. 1 and Fig. 4. The interior 14 is a liquid and preferably silicone. As is known, the specific gravity of the silicone used in this lens can be the same as or very similar to that of the aqueous solution in the human eye. This results in either no or negligible deformation of the liquid portion of the lens by gravity. The liquid silicone 14 may have the same or similar refractive index as the solid components 12. The solid posterior radius of portion 12a prevents deformation of the posterior refracting surface. The radius of the portions 12a or 12b can be changed, during manufacturing, to select the desired power for the lens. Also, the power can be changed during manufacturing or after implantation by changing the volume or refractive index of the liquid 14 in the lens optic 10.

[0020] In accommodating, the posterior surface portion 12a is pushed forward (to the left in Figs. 1 and 4) by vitreous cavity pressure with constriction of the ciliary muscle. The anterior portion 12d bulges with increased curvature, that is decreased radius, of the anterior portion 12d such as illustrated in Fig. 4.

[0021] Example dimensions are 4.5 – 10.5 mm in overall diameter of portion 12b from D to D in Fig. 1, up to a 5 mm diameter portion 12d, and a 3-6 mm thickness (from right to left) in Fig. 1. A typical thickness for the solid silicon portions 12a and 12b is between 0.5 mm and 1.5 mm. The thickness of the anterior membrane 12d is very thin, preferably about that of

a toy balloon, and the thickness of the annulus 12c is approximately two times that thickness to give sufficient flexibility to the solid posterior lens. The thickness at the hinge 18 area can be 0.1 mm. The hinge area 18 can be a "V" shape as shown but can be a square groove. Also, hinges 22 preferably are provided between 12c and 12a to facilitate anterior movement of the posterior optic 12a.

[0022] Furthermore, the power of the present lens can be changed after implantation in the eye by either injecting or removing the liquid preferably silicone from the optic 10 or changing its refractive index.

[0023] The diameter of the portion 12d as well as its area can be less or more than that of the posterior portion 12a, dependent on the refractive range desired in the design of the lens.

[0024] As noted above, the haptics 16 may have a space or thin area 18 forming a hinge across their surface adjacent to the optic. This facilitates movement of the optic anteriorly and posteriorly relative to the outer ends of the haptics.

[0025] Turning now to the Figs. 5-6 embodiment, it will be noted that anterior portion 12d is thinner in the middle, which will bulge more as shown in Fig. 6 under increased vitreous pressure. Alternatively, the portion 12d can have parallel sides, that is, not be thinner in the middle. Also, the back surface of portion 12a can be polyspheric or toric.

[0026] Turning now to Figs. 7-8, these illustrate two further configurations. In Figs. 7A and 7B the posterior center portion 12a is thin and not a large solid central portion like that shown in Figs. 5 and 6. Also, anterior portion 12d is very thin, thinner than 12a, so as to enable bulging under increased vitreous pressure which at the same time causes indentation of the posterior thicker membrane 12a to change the refracting convex surface into a concave surface further increasing the power of the optic.

[0027] Fig. 8A is another alternative embodiment wherein both the posterior portion 12a' and anterior portion 12e comprise solid portions 12b and 12e, and the flexible annular portion 12a is thin and very flexible, and annular portion 12d is even thinner. An increase in vitreous pressure causes the portion 12e to move forward.

[0028] Fig. 8A demonstrates an optic with a convex solid optical surface on both the anterior 12e and posterior 12a' optical surfaces. Fig. 8B has a convex solid anterior optical surface 12e and a concave solid posterior optical surface 12b whereby more anterior movement of the anterior convex surface compared to a smaller movement of the posterior concave surface further increases the optical power of the lens. Fig. 8C is a further modification of the optic whereby the anterior optical surface 12d is thin and convex and the posterior solid optical

surface 12b is concave. Fig. 8D is another variation with a thick posterior surface 12c and a thin convex solid anterior surface 12d.

[0029] Figs. 9-12 illustrate various different haptic arrangements for the lens embodiments herein. Figs. 9 and 11 illustrate the anterior side of the lens and Figs. 10 and 12 illustrate the posterior side. In each instance haptics 16 are provided which may be hinged at 18 to the optic. Preferably, flexible loops 17 are included at the ends of the haptics and are positioned in close proximity to, or to seat lightly against, the capsular bag cul-de-sac wall. The cul-de-sac wall deflects these loops inwardly slightly to better conform closely to the curvature of the cul-de-sac wall and accurately center the lens in the capsule bag.

[0030] As is well known in the art, an intraocular lens is implanted in the capsular bag of the eye after removal of the natural lens. The lens is inserted into the capsular bag by a generally circular opening cut in the anterior capsular bag of the human lens and through a small opening in the cornea or sclera. The outer ends of the haptics, or loops, are positioned in the cul-de-sac of the capsular bag. The outer ends of the haptics, or the loops, are in close proximity with the bag cul-de-sac, and in the case of any form of loops, the loops are deflected. Knobs can be provided on the outer end portions of the loops for improved securement in the capsular bag cul-de-sac with fibrosis, which develops in the capsular bag following the surgical removal of the central portion of the anterior capsular bag and the lens nucleus and cortex.

[0031] Accordingly, there has been shown and described a lens that comprises an optic of solid and liquid silicone and plate haptics or loops haptics, with preferably fixation and/or centration protuberances at the ends of each haptic plate.

[0032] Various changes, modifications, variations, and other uses and applications of the subject invention will become apparent to those skilled in the art after considering this specification together with the accompanying drawings and claims. All such changes, modifications, variations, and other uses of the applications which do not depart from the spirit and scope of the invention are intended to be covered by the claims which follow.

CLAIMS

1. An accommodating intraocular lens in which the optic comprises
an integral central optical system supported by a solid fixed radius, flexible annular peripheral optical component, a central anterior optical component comprising a thin deformable membrane, a central liquid optical material, and a posterior central flexible optic component suspended from the solid annular support, the flexible posterior component is thicker and less resilient than the thinner anterior membrane, and the posterior optical surface being designed to move forward and compress the central liquid optical material to thereby cause the thin anterior membrane to bulge forward increasing its refractive power upon an increase of vitreous cavity pressure with ciliary muscle contraction and is configured such that an increase in vitreous cavity pressure converts the flexible posterior convex membrane into a concave surface.
2. The lens according to Claim 1 wherein the posterior refracting surface is solid and convex.
3. The lens according to Claim 1 wherein the posterior refracting surface is solid and concave.
4. The lens according to Claim 1 wherein both the anterior and posterior refractive surfaces are convex and solid.
5. The lens according to Claim 1 wherein the anterior refractive surface is convex and solid and the posterior refractive surface is concave and solid.
6. A lens according to Claim 1 wherein one surface of the optical component is a membrane and the other a solid optical surface.
7. A lens according to Claim 1 wherein the anterior and posterior surfaces are membranes.
8. A lens as in Claim 1 wherein the whole optical system is designed is to be supported within the eye by haptics.
9. A lens as in Claim 8 wherein fixation devices are on the distal ends of the haptics.
10. A lens as in Claim 8 wherein the haptics are plate haptics.
11. A lens as in Claim 8 wherein the haptics have hinges adjacent the optical component.
12. A lens in Claim 8 wherein the optical system is movable relative to the outer ends of the haptics.