BI-CONCAVE SMALL INCISION INTRAOCULAR LENS

BACKGROUND OF THE INVENTION

An intraocular lens, which is commonly referred to as an "IOL", is used to replace the natural lens of the human eye following cataract surgery. To implant an IOL, an incision is made in the eye, and the IOL is inserted through the incision and fixed within the eye in accordance with known techniques. The incision in the eye creates trauma and a possibility of infection. For these and other reasons, it is desirable to minimize the length of the incision.

An IOL commonly includes an optic and fixation means for fixing the optic within the eye. To minimize the size of the incision, both the optic and the fixation means can be made of deformable material so that they can be rolled or deformed for insertion through a relatively small incision. One such IOL is shown in published British Patent Application No. 2,114,315. Although folding or deforming the optic and fixation means for implantation is desirable to reduce the length of the incision, the length of the incision could be further reduced through the use of a foldable optic which employs a lower volume of material.

It is also known to construct an IOL having high magnification by utilizing multiple air lenses in tandem. Each of the air lenses has one or more gas-filled bubbles. One such construction is shown in Levy et al U.S. Pat. No. 4,074,368. The IOL shown in this patent is constructed of rigid material and has a very substantial axial dimension. Accordingly, it is not suited for implantation through a small incision.

SUMMARY OF THE INVENTION

This invention provides a thin IOL which uses a minimum volume of material so that it is easily implantable through a very small incision. The IOL can be constructed of soft, flexible, deformable materials so that it can be folded or deformed for insertion through the incision into the eye. The optic contains a gas which can be compressed when the IOL is folded to reduce the volume of the optic.

The IOL includes an optic body which has anterior and posterior faces and an interior gas-filled chamber. The chamber has forward and rear surfaces which extend generally transverse to the optical axis of the optic.

It is necessary that the optic be a positive lens in that it must focus light on the retina. As explained more fully hereinbelow, the presence of the gas-filled chamber in the optic body requires at least one of the forward and rear surfaces of the chamber be concave. To minimize the material required for the optic body and to enhance thinness of the optic, preferably the forward and rear surfaces and the anterior and posterior faces are concave. However, to the extent that additional material for the optic body can be tolerated, the anterior and posterior faces and one of the forward and rear surfaces need not be concave and may be, for example, planar or convex. However, if one of the forward and rear surfaces is convex, its radius of curvature must be greater than the radius of curvature of the concave surface in order that the optic can function as a positive lens which will focus light on the retina. In this regard, the functional or light-focusing surfaces of the optic body are the forward and rear surfaces rather than the anterior and posterior faces.

The advantage of employing the gas-filled chamber in minimizing the material used for the optic body and in maximizing thinness of the optic can best be understood by considering the basic function of the optic which is to focus the light on the retina. Generally, the ability of an IOL to focus light on the retina is a function of the difference in refractive indices of the optic and the liquid of the eye, e.g., the aqueous humor, and the radii of the forward and rear surfaces of the chamber. If the difference in the refractive indices is increased, the radii can be lengthened, and this results in a thinner optic and a lower volume of material for the optic body.

The refractive index of the aqueous humor is approximately 1.336, and the refractive index for PMMA, which is a commonly used material for the optic, is about 1.491. However, the refractive index for most applicable gases is essentially 1.0. By utilizing a gas-filled chamber, the difference in the refractive indices is approximately doubled as compared to PMMA. Accordingly, the radii of the forward and rear surfaces of the chamber can be lengthened to thereby reduce the thickness of the optic compared to a conventional optic.

Only one of the gas-filled chambers is required. This further minimizes the thickness of the optic.

Because the walls of the optic are thin, additional strength can be imparted to them if they are joined together at central regions of the walls. This makes the chamber of generally annular configuration.

The forward and rear surfaces of the chamber may be defined by a very thin coating. The coating reduces the migration of gas out of the chamber through the walls of the optic.

The optic and fixation means are both preferably constructed of a soft, deformable material, such as silicone. This enables the IOL to be folded or deformed to facilitate implantation through a small incision. The fixation means preferably surrounds the optic and serves as a frame to help support the flexible optic.

A soft, deformable optic having a gas-filled chamber can be used to adjust or vary the diopter power of the IOL. This can be accomplished by placing a quantity of gas in the chamber to control the spacing between, and/or curvature of, the forward and rear surfaces. By controlling the spacing between, and/or curvature of, these surfaces, the diopter power of the IOL can be adjusted the desired amount. This feature of the invention does not require that the forward or rear surfaces be concave but only that they be movable or curvable so that the spacing or curvature thereof can be varied with the gas pressure in the chamber. If this feature is employed, the central regions of the walls of the optic are preferably resiliently joined together or left unjoined.

The placing of the desired quantity of gas in the chamber to adjust the diopter power can be carried out in various ways, such as by inflating the chamber to provide the desired quantity of gas or over-inflating the chamber and thereafter deflating the chamber to provide the desired quantity of gas. The desired quantity of gas can be placed into the chamber before and/or after implantation of the IOL. The usual ambient pressure or temperature changes are not sufficient to meaningfully alter the diopter power.

The invention, together with additional features and advantages thereof, may best be understood by refer-