ADJUSTABLE INTRAOCULAR LENS

BACKGROUND OF THE INVENTION

The present invention relates generally to intraocular lenses, and more particularly to intraocular lenses whose focusing performance can be adjusted externally after implantation in an individual's eye, without a need for any invasive procedure.

The lens and the cornea of the human eye provide a combined refractive power of approximately 60 diopters (D), with the cornea providing about 40 D of the power and the lens providing about 20 D of the refractive power. Certain diseases of the eye, such as cataracts, cause the lens to become progressively opaque. The opacity typically worsens over time, and can ultimately result in blindness. It is typically necessary to surgically remove the opaque lens to allow an unobstructed transmission of light to the retina. The removal of the lens, however, deprives the eye from the substantial refractive power that the lens provides.

When the natural lens is removed from the eye, an intraocular lens (IOL) can be implanted in the eye to assist the eye in focusing light onto the retina. Intraocular lenses typically provide one or more fixed focusing performances. Typically, the needed refractive correction(s) is (are) determined before implantation of the IOL in the eye. Such pre-operative predictions of the needed corrective power are sometimes not sufficiently accurate. Furthermore, once implanted, an IOL can shift position within the eye, thereby causing a loss of focus. Hence, an individual having an implanted IOL may require additional corrective devices, such as glasses, to acquire the desired visual acuity.

Accordingly, it is object of the present invention to provide an intraocular lens whose focusing performance can be modified in situ.

It is another object of the invention to provide an intraocular lens whose focusing performance can be externally modified after implantation in the eye.

It is yet another object of the invention to provide an intraocular lens whose focusing performance can be adjusted over a selected range.

SUMMARY OF THE INVENTION

The present invention attains the above and other objects by providing an intraocular lens whose focusing performance can be adjusted over a selected range after implantation in a patient's eye without a need for an invasive procedure. In particular, the focusing performance of an IOL according to the invention can be modified by application of energy, such as magnetic or electric energy, supplied from an external source to the IOL. An intraocular lens according to the teachings of the invention includes an optical chamber deformable under influence of pressure from a fluid. The IOL further includes a reservoir, in fluid communication with the optical chamber, for storing an optical fluid. A valve regulates the fluid communication between the reservoir and the optical chamber.

As used herein, the term "optic" or "optical body" is intended to encompass the component(s) within the intraocular lens of the present invention that cumulatively enable the intraocular lens to focus the light. The optic can include an optical chamber and optical fluid within such chamber, as well as one or more physical lens structures, if desired. The term "intraocular lens", as used herein, encompasses all of the above described optical elements and other structures such as haptics useful for attaching the IOL to the eye as well as other structures elaborated below.

The IOL can further include a pump capable of being actuated by an energy source external to the eye to cause a flow of a selected volume of the optical fluid between the reservoir and the optical chamber. A flow of the optical fluid into and/or out of the optical chamber selectively varies an amount of fluid in the optical chamber. The change in the amount of fluid in optical chamber can vary a pressure exerted on the flexible portion(s) of the optical chamber to cause a change in radius of curvature of the flexible portion (s) and/or vary a distance between optical surfaces of the optical chamber. Such changes in the optical chamber can lead to a change in the focusing performance of the IOL.

The external energy source can include, but is not limited to, a magnetic field generator, an electric field generator, or a source of photons, such as a laser. In one preferred embodiment, an oscillatory magnetic field is employed for actuating the pump. In another embodiment, a rotating magnetic field is employed for activating the pump.

In general, the index of refraction of the optical fluid useful in the present invention can have any value. In most implementations, however, the index of refraction of the optical fluid is preferably selected to be greater than approximately 1.337. One preferred embodiment of the invention employs silicone with an index of refraction of about 1.4 as the optical fluid.

In many implementations, the IOL can include an optical body having two optical elements, at least one of which has a flexible convex region. These elements form an optical chamber therebetween. In such an embodiment, pumping a volume of the optical fluid into the chamber increases the hydrostatic pressure within the optical chamber and hence causes a decrease in the radius of curvature of the flexible region of the chamber. Such a decrease in the radius of curvature, in combination with the focusing performance of the fluid, leads to an increase in the focusing performance of the intraocular lens.

The IOL device can also include one or more haptics to allow fixation of the lens within the eye. The haptics can also include the reservoir of fluid for use in modifying the shape of the optical chamber.

One embodiment of the present invention provides an intraocular lens that employs a gear-pump. Such an intraocular lens includes an optical body having at least an optical chamber with at least a flexible region deformable in response to an applied pressure. A reservoir, which is in fluid communication with the optical chamber through a valve positioned between the reservoir and the optical chamber, stores a selected volume of an optical fluid. The gear pump is configured to be actuated by an energy source positioned external to the eye to cause the optical fluid to move, through the valve, between the optical chamber and the reservoir.

The gear pump can include a pair of inter-locking gears formed, for example, of silicone rubber. At least one of the gears is selected to be magnetically rotatable, for example, by implanting a permanent magnet in the silicone rubber. An external magnetic field generator can be utilized to apply a rotating magnetic field to the magnetic gear to cause a rotation thereof. The rotation of the magnetic gear in turn causes a rotation of the other gear, i.e., the gear engaged with the magnetic gear, in an opposed direction. The combined rotation of the gears controls the flow of the optical fluid between the reservoir and the optical chamber of the lens.

Another preferred embodiment of the invention employs a peristaltic pump for providing fluid communication