# ACCOMMODATING INTRAOCULAR LENS

## BACKGROUND OF THE INVENTION

The present invention is directed to intraocular lenses (IOLs). More particularly, the invention relates to IOLs which are adapted to provide bidirectional accommodating movement in the eye.

The human eye includes an anterior chamber between the cornea and iris, a posterior chamber, defined by a capsular bag, containing a crystalline lens, a ciliary muscle, a vitreous chamber behind the lens containing the vitreous humor, and a retina at the rear of this chamber. The human eye has a natural accommodation ability. The contraction and relaxation of the ciliary muscle provides the eye with near and distant vision, respectively. This ciliary muscle action shapes the natural crystalline lens to the appropriate optical configuration for focussing light rays entering the eye on the retina.

After the natural crystalline lens is removed, for example, because of cataract or other condition, a conventional, monofocal IOL can be placed in the posterior chamber. Such a conventional IOL has very limited, if any, accommodating ability. However, the wearer of such an IOL continues to require the ability to view both near and far (distant) objects. Corrective spectacles may be employed as a useful solution. Recently, multifocal IOLs without accommodating movement have been used to provide near/far vision correction.

Attempts have been made to provide IOLs with accommodating movement along the optical axis of the eye as an alternative to shape changing. Examples of such attempts are set forth in Levy U.S. Pat. No. 4,409,691 and several patents to Cumming, including U.S. Pat. Nos. 5,674,282 and 5,496,366. The disclosure of each of these patents is incorporated herein by reference. These lenses are biased to be located in the posterior-most position in the eye under rest or resting conditions. When near focus is desired, the ciliary muscle contracts and the lens moves forwardly (positive accommodation). In the absence of ciliary muscle contraction, the lens moves rearwardly to its posterior-most resting position. One problem that exists with such IOLs is that they often cannot move sufficiently to obtain the desired accommodation.

It would be advantageous to provide IOLs adapted for accommodating movement which can achieve an increased amount of accommodation.

## SUMMARY OF THE INVENTION

New accommodating IOLs have been discovered. The present accommodating IOLs take advantage of the ability of the eye to move the present IOLs bidirectionally, that is both forwardly (anteriorly) and rearwardly (posteriorly), in the eye in response to normal accommodative stimuli. Thus, the present lenses provide for controlled vision correction or focusing for both near objects and far or distant objects. Further, because bidirectional accommodating movement is provided and the optics of the IOLs have optical powers which take into account such bidirectional movement, a greater overall range of accommodation is often achieved. Thus, the present IOLs provide for controlled accommodating movement and/or an increased range of accommodating movement. The present IOLs are straightforward in construction, can be implanted or inserted into the eye using systems and procedures which are well known in the art and function effectively with little or no additional treatments or medications being required.

In one broad aspect of the present invention, intraocular lenses (IOLs) are provided and comprise an optic and a movement means or movement assembly. The optic is adapted to focus light toward the retina of an eye and has a far vision correction power for infinity reduced by a diopter power increment. For example, the optic has an optical power or a vision correction power which results in myopia at a neutral resting state of the eye. That is, the wearer of such an IOL experiences relative myopia viewing a distant (far) object, for example, an object located 20 or more meters from the eye, with the optic in a neutral resting state (or position) of the eye.



As used herein, the term "neutral resting state" refers to the state of the eye which exists without visual stimuli, for example, in a totally darkened room or in a luminous but completely empty visual field. Such a "neutral resting state" can be considered the natural resting state of the eye. The neutral resting state of the eye can be referred to as "tonic accommodation", "space myopia" and "sky myopia". Viewed from a different perspective, the neutral resting state of the eye (with the natural crystalline lens present) exists with the eye focused for objects in a range of about one meter to about two meters from the eye.

The starting point for accommodation in accordance with the present invention is at a neutral resting state of the eye, rather than infinity as in the previously discussed prior art accommodating IOLs which were biased in the posterior-most position with the eye at rest. In a neutral resting state of the mammalian or human eye, the parasympathetic/cholinergic system of the mammal or human maintains ciliary muscle tone, i.e., the ciliary muscle is partially contracted and zonular tension is partially relaxed. In this state, with a natural lens in place, the natural lens is spherical and in a forward position which increases the diffractive power of the eye. Thus, the eye, in the absence of visual stimuli, is in a neutral resting state or a "tonic accommodative" state and with appropriate stimulus is capable of both active or controlled positive accommodation and active or controlled negative accommodation. The present accommodating IOLs are able to adjust to distance (negative accommodation) and near (positive accommodation) in response to normal ciliary muscle action upon stimulation of the parasympathetic nervous system and/or the sympathetic nervous system.

In a very useful embodiment, the optic has a far (or distance) vision correction power for infinity (distance refraction) reduced by a diopter power increment in a range of more than 0.5 to about 2.5 or about 3.5 diopters, more preferably in a range of about 1 to about 2 diopters. Thus, the optic which is prescribed for the wearer of the IOL has a far vision correction power equal to the far vision correction power calculated or determined at infinity reduced by a diopter power increment, as described herein. This diopter power increment reduction often results in the IOL wearer experiencing relative myopia when viewing a distant object with the IOL in a neutral resting position in the eye. The present IOLs are adapted to move posteriorly in the eye from a resting position to provide negative accommodation, thereby alleviating this relative myopia.

The movement means or movement assembly acts, in cooperation with the eye, to move the optic both anteriorly and posteriorly to provide both positive and negative accommodation, respectively. In one embodiment, the movement means or movement assembly is coupled to the optic and is adapted to cooperate with the eye to move the optic anteriorly in the eye and posteriorly in the eye to effect positive accommodating movement of the optic and negative accommodating movement of the optic, respectively.

The present IOLs are preferably provided with a movement means or a movement assembly which, in cooperation