VARIABLE FOCUS LENS

BACKGROUND OF THE INVENTION

The present invention relates generally to a variable focus lens and, in particular, to an apparatus for varying the power of and providing astigmatism correction in an intraocular lens.

The lens of the human eye is located centrally behind the pupil and is protected by the cornea. In the normal eye, the lens is clear and is substantially symmetrical, with opposed convex surfaces defining generally spherical sections. The lens and the cornea cooperate to focus light on the retina. The retina in turn cooperates with the nerves and the brain, so that light impinging on the retina is perceived as an image.

The light refraction which takes place in the cornea and the lens translates into an optical correction of about 60 diopters, with the cornea accounting for about 40 diopters and the lens accounting for about 20 diopters. Other refracting structures also are present in the eye, but are disregarded to simply the subject explanation.

A cataract is a condition where the normally clear lens of the eye becomes progressively opaque. This opacification typically occurs over an extended period of time, and the amount of light which passes through the lens decreases with increasing degrees of opacity. As the ability of the cataract lens to transmit light decreases, the ability of the eye to perceive images also decreases. Blindness ultimately can result. Since there are no known methods for eliminating the opacity of a cataract lens, it generally is necessary to surgically remove the opaque lens to permit the unobstructed passage of light through the pupil to the retina. The cataract lens is removed through a generally horizontal incision made at the superior part of the juncture where the cornea and sclera meet.

Once the lens has been surgically removed, light can be readily transmitted through the pupil and toward the retina.

As noted above, the lens of the eye performs a significant light focusing function. Consequently, with the lens removed, the optical system of the eye is left about 20 diopters "short" and light is no longer properly focused on the retina. Eyeglasses, contact lenses and intraocular lenses are the three types of optical aids that commonly may be employed after cataract surgery to refocus the light on the retina.

Eyeglasses include lenses which are spaced from the cornea of the eye. The air space between the lens and the cornea causes an image magnification of more than 7%. Unfortunately, the brain cannot assimilate this magnification in one eye, and as a result an object appears double. This is a particular problem if the individual had only one cataract eye. Eyeglasses also substantially limit peripheral vision.

Contact lenses rest directly on the cornea of the eye. thus eliminating the air space. As a result, there is a much smaller image magnification with contact lenses than there is with eyeglasses, and the brain typically can fuse the images perceived by an eye with a contact lens and one without. Contact lenses, however, are less than perfect. For example, contact lenses are quite fragile and can be easily displaced from their proper position on the cornea. Additionally the lenses must be periodically replaced because of protein build-up on the surface of the lens which can cause conjunctivitis. Furthermore, many of the elderly people who require cataract operations do not have the required hand coordination to properly remove or insert the lens.

Intraocular lenses first because available as optical aids to replace removed cataract lenses in about 1955. These lenses are placed in the eye, and thus closely simulate the optics of the natural lens which they are replacing. Unlike eyeglasses, there is virtually no image distortion with a properly made and placed intraocular lens. Also unlike contact lenses, there is no protein build-up on the intraocular lenses and the lenses require no care by the patient.

To place the lens in the eye, the surgeon ordinarily makes an incision or opening in the cornea which aligns with the pupil, and the surgeon passes the lens through the opening. The attachment members of the lens are flexible and can be bent to pass through the opening. Accordingly, the minimum length of opening which must be made and is ordinarily determined by the diameter of the substantially rigid lens body, or optic, usually having a circular periphery. It is, of course, desirable to make the opening in the cornea as small as possible to minimize the risk of damage to the eye.

The current practice in the implantation of intraocular lenses is to replace a normal crystalline human lens of the eye removed at the time of surgery, such as in cataract surgery, with an intraocular lens such as an anterior chamber lens or posterior chamber lens formed of PMMA (polymethyl methacrylate) material. However, one of the present problems with intraocular lenses is that it is necessary to decide on the power of the lens preoperatively. This can be accomplished, for example, by performing an ultrasound scan and/or evaluating the patient's refraction preoperatively and then making a clinical estimate of the proper power of the lens in order to determine proper refraction of the eye. However, even with the best medical techniques and sophisticated optical instruments available, ophthalmologists have never been able to correct for accommodation of vision from distance to near vision and the power of the lens implant is seldom accurate enough for the patient to function without the use of glasses for accurately focused distance and near vision.

The prior art intraocular lens typically is either of plano-convex construction or double convex construction, with each curved surface defining a spherical section. The lens is placed in the eye through the same incision which is made to remove the cataract lens. As noted above, this incision typically is made along the superior part of the eye at the juncture of the cornea and the sclera. About one third of all postoperative patients will have significant astigmatism and, approximately one third will need a spherical adjustment in their postoperative glasses to see clearly. In virtually all instances, the surgery itself induces astigmatism which fluctuates significantly during the first few weeks, or even months, after the surgery.

Postoperative induced astigmatism is attributable to the healing characteristics of the eye adjacent the incision through which the cataract lens is removed and the intraocular lens is inserted. More particularly, the sutured incision in the eye tends to heal more slowly and less completely as compared to incisions in the skin. For example, a sutured incision in skin typically heals in five to seven days, whereas a comparable incision in the eye may take eight weeks to a year to properly heal depending on the method of suturing. This slow healing rate is