

## MULTIFOCAL LENS DESIGNS WITH INTERMEDIATE OPTICAL POWERS

### BACKGROUND OF THE INVENTION

#### 1. Field of the Invention

The present invention relates generally to multifocal lens designs with intermediate optical powers, and more particularly pertains to multifocal lens designs with intermediate optical powers which provide for visual acuity at intermediate distances by adding one or more intermediate optical power annular rings to a multifocal concentric annular ring lens.

#### 2. Discussion of the Prior Art

The present invention pertains to ophthalmic lenses, and in particular to contact lenses such as soft hydrogel contact lenses, and intraocular lenses, having more than one optical power or focal length.

It is well known that as an individual ages, the eye is less able to accommodate, i.e., bend the natural lens in the eye in order to focus on objects that are relatively near to the observer. This condition is referred to as presbyopia, and presbyopes have in the past relied upon spectacles or other lenses having a number of different regions with different optical powers to which the wearer can shift his vision in order to find the appropriate optical power for the object or objects upon which the observer wishes to focus.

With spectacles the process involves shifting one's field of vision from typically an upper lens portion far power to a lower lens portion near power. With soft or hydrogel contact lenses, however, this approach has been less than satisfactory. The contact lens, working in conjunction with the natural lens, forms an image on the retina of the eye by focusing light incident on each part of the cornea from different field angles onto each part of the retina in order to form an image. This is demonstrated by the fact that as the pupil contracts in response to brighter light, the image on the retina does not shrink, but rather, light comes through a smaller area of the lens to form the entire image.

Similarly, for a person that has had the natural lens of the eye removed because of a cataract condition and an intraocular lens inserted as a replacement, the ability to adjust the lens (accommodate) to the distance of the object being viewed is totally absent. In this case, the lens provided is usually set at a single infinite distance focal power, and spectacles are worn to provide the additional positive optical power needed for in-focus closer vision. For such a patient, a functional multifocal lens would be particularly useful.

It is also known in the art that under certain circumstances the brain can discriminate between separate competing images by accepting an in-focus image and rejecting an out-of-focus image.

One example of this type of lens used for the correction of presbyopia by providing simultaneous near and far vision is described in U.S. Pat. No. 4,923,296 to Erickson. This patent discloses a lens system which comprises a pair of contact lenses, each having equal areas of near and distant optical power, with the lens for one eye having a near upper half and a distant lower half and the lens for the other eye having a distant upper half and near lower half. Together they provide at least partial clear images in both eyes, and through suppression by the brain of the blurred images, allow alignment of the clear images to produce an in-focus image.

U.S. Pat. No. 4,890,913 to de Carle describes a bifocal contact lens comprising a number of annular zones having

different optical powers. The object in the design of this lens is to maintain, at all times regardless of pupil diameter, an approximately equal division between near and distant powers, which requires between six and twelve total zones on the lens.

Another attempt at providing a bifocal contact lens is described in U.S. Pat. No. 4,704,016 to de Carle. Again, this lens attempts to maintain, at all times regardless of pupil diameter, an approximately equal division between near and distant powers.

U.S. Pat. No. 5,448,312 entitled PUPIL TUNED MULTIFOCAL OPHTHALMIC LENS, discloses a multifocal concentric ophthalmic lens for presbyopic patients constructed with three general annular lens portions in a multifocal design. A central circular portion of the lens has only the patient's distance corrective power, and is surrounded by a first inner annular portion, which can consist of multiple annular rings having an inner radial portion which enhances the patient's near focal power encircled by radial portions of substantially equal cumulative amounts of distance and near optical power focal correction for the patient. This is surrounded by a second outer annular portion, which can also consist on one or more annular rings having additional distance focal power near the periphery of the optical surface area of the ophthalmic lens. Each annular ring has either a near or distance optical power and works in combination with other lens portions to yield the desired focal ratio in that portion of the lens.

Trifocal spectacles are also well known in the prior art in which an upper spectacle lens portion has a prescription for far vision, a lower spectacle lens portion has a prescription for near vision, and an intermediate spectacle lens portion, positioned between the upper and lower lens portions, has a prescription for intermediate vision. Moreover, blended trifocal and multifocal spectacles are also known in which an upper lens portion has a prescription for far vision, and a lower lens portion has a prescription for near vision, and an intermediate lens portion has a blended prescription which changes gradually from the optical power for the upper portion to the optical power for the lower lens portion.

However, these concepts are not readily extendible to contact or intraocular lenses, as a wearer cannot shift his vision through different upper and lower areas of a contact or intraocular lens. The only change that the eye makes with respect to a contact or intraocular lens is an involuntary control over the diameter of the pupil, which decreases in bright light and increases in dim light.

### SUMMARY OF THE INVENTION

It is an object, therefore, of the present invention to provide an ophthalmic lens for a presbyope that yields improved visual acuity in general, and in particular, matches the focal requirements of intermediate distance conditions.

The present invention provides a contact or intraocular lens which matches the distribution of near, intermediate and distance focal vision corrections to the type of human activity typically undertaken in various illumination conditions. The present invention also matches the particular dimensions of a contact lens to suit the size of the pupil of the wearer as a function of illumination intensity. The ophthalmic lens is designed to provide predominantly distance correction under high illumination, nearly evenly divided distance and near corrections under moderate illumination, and provide intermediate vision correction under low to moderate illumination levels. The lens is also specifically designed to match the wearer's pupil size as a