CONCENTRIC RING SINGLE VISION LENS DESIGNS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to concentric ring, single vision lens designs. More particularly, the subject invention pertains to concentric ring, single vision lens designs which improve the depth-of-focus of the lens relative to current spherical single vision contact lenses or intraocular lenses by using a plurality of additional optical radii of curvature on a peripheral area of the lens.

2. Discussion of the Prior Art

Current prior art contact lens or intraocular lens designs attempt to correct for refractive (spherical) error by using one radius of curvature on each of the front and back optical surfaces of the lens. One disadvantage of this prior art approach is that light rays passing through the peripheral areas of the lens tend to focus in the eye in front of those passing through the center of the lens. This prior art approach restricts its depth-of-focus or field, and the quality of the optical image formed.

In the prior art as exemplified by U.S. Pat. Nos. 5,050,981 and 5,220,359, it has been shown that by using an in vivo ocular image quality measurement device, such as an in vivo modulation transfer function (MTF) measurement device, ocular aberrations can be reduced which results in an increase in visual acuity and performance.

U.S. Pat. No. 5,181,053 to Brown discloses a multifocal contact lens having a spherical curve in the center region of the concave surface and an aspheric curve which surrounds the center spherical region. The center spherical region improves distance night vision by providing a spherical center in the optical zone through which the eye sees far distant objects, compensating for the expansion of the eye pupil at night into radially distant areas of the aspheric curve having greater aspheric curvature for near vision and less curvature of the aspheric curve closer to the central spherical region. One major disadvantage of this contact lens design is the use of corrective aspheric radii, which are difficult to measure and manufacture in practice.

SUMMARY OF THE INVENTION

Accordingly, it is a primary object of the present invention to provide multiple concentric ring, single vision lens designs which improve the depth-of-focus and image quality of the lens relative to current spherical single vision contact lenses or intraocular lenses by placing at least one additional peripheral optical radius on the front or back surface of the lens.

A further object of the subject invention is the provision of concentric ring, single vision lens designs which provides at least one, and preferably a plurality of, concentric annular rings in the periphery of the optic zone of the lens. The arrangement of optic powers in the concentric annular rings includes a mixture of the basic spherical refractive power and other annular rings with less plus or greater minus spherical refractive power, arranged to mediate spherical aberrations and improve visual acuity. The concentric annular ring design corrects peripheral, aperture-dependent ocular aberrations in a discrete, zonal fashion. It can also eliminate the use of corrective aspheric radii as in the Brown patent, which are difficult to measure and manufacture in practice.

In a typical eye, ocular aberrations increase as the diameter of the pupil aperture increases. The present invention

compensates for this effect by designed changes in the spherical radius, in concentric annular zones, as the diameter of the pupil aperture increases. In contact lenses, the concentric annular rings are preferably placed on the rear surface of the contact lenses to minimize flare and glare problems which might be encountered if the concentric annular rings were placed on the front surface thereof.

The method of selection of the power/radius changes in the concentric annular rings can be from empirical patient data, classified into types, or the result of computer optical ray tracing, wherein the (spherical) aberration is compensated for in concentric annular rings, or the result of direct in vivo measurement of ocular aberrations by a suitable apparatus such as an aberroscope or MTF point spread device, such that in vivo lenses can be specifically tailored to an individual, or are the result of analyzing the patient population as a whole for classification into inventory stock keeping unit types.

In accordance with the teachings herein, the present invention provides a concentric annular ring, single vision lens which focuses light rays passing through the periphery of the lens at or near the same focal plane as light rays passing through the center of the lens, thereby improving its depth-of-focus and image quality. The lens comprises a front surface and an opposite back surface, and one of the front and back surfaces defines a central area comprising a circular disc having a spherical surface corresponding to a basic prescription Rx spherical refractive power. A plurality of annular rings surround the central area, and have a combination of the basic prescriptive spherical refractive power and a less plus or greater minus spherical refractive power, to mediate spherical aberration and improve visual acuity.

In greater detail, the lens can comprise a contact lens to be worn on the cornea of the eye, particularly a soft hydrogel contact lens, or an intraocular lens. The central area and the annular rings are preferably formed on the back surface of a contact lens to minimize flare and glare problems. In different embodiments, the plurality of annular rings have less plus spherical power for a hyperopic prescription, or greater minus spherical power for a myopic prescription. In preferred embodiments, the central area is surrounded by a plurality of alternating sphere power and sphere' power annular rings, wherein the sphere' power comprises a spherical power which is less plus or more minus than the spherical power of the central area. Moreover, the widths of individual annular rings can be different to generate a power profile which varies to generate different amounts of minus power with increasing distance from the center.

Moreover, ocular in vivo image quality measurement devices can be used to optimize the ocular image quality in the concentric annular ring designs to produce even more improved designs. This is accomplished by using an in vivo image quality measurement device, such as an aberroscope or MTF point spread measuring device, to measure and decrease the sum of the aberrations of the combination of the concentric lens and the eye system.

The present invention also provides a method of designing a concentric annular ring, single vision lens as described herein which comprises performing an in vivo image quality analysis with an in vivo quality analysis instrument of a first design of the lens on the eye to measure residual aberrations, and then redesigning the lens to reduce the measured residual aberrations and improve visual acuity and performance. The redesign of the lens can include aspherizing the surface opposite the surface defining the central area and the