CONCENTRIC ANNULAR RING LENS DESIGNS FOR ASTIGMATISM

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to concentric annular ring lens designs for astigmatic patients, and more particularly pertains to such lens designs which reduce the sensitivity of the patient to toric axis misalignment, thus reducing the required number of stock keeping units in inventory (the total number of different prescriptions which are maintained in stock and can be prescribed) for a toric product.

The present invention provides a novel approach for correcting ametropias such as astigmatism, hyperopia and myopia, with a primary correction for astigmatism.

2. Discussion of the Prior Art

Currently, toric lenses are manufactured in the prior art with the following design features:

a. a toric curve on the front or back surface of the lens;

b. prism ballast and slab-off features on the front surface of the lens;

c. the non-toric surface is spherical.

These prior art designs correct astigmatism adequately only if the axis of the cylindrical power is accurately aligned with respect to the axis of the astigmatic cornea. A misalignment of the axes (greater than 10°) results in a substantial loss of visual acuity. The primary source of this misalignment in soft hydrogel contact lenses is poor rotational stability.

In conventional prior art toric lens designs, a single toric surface comprising a major and minor axis is placed in the optical portion of either the front or back surface of the lens. In addition, the axes of the toric lens are usually stabilized in relation to the patient's corneal axes through the use of either a prism ballasted/slab-off feature or a double slab-off feature placed on the front surface of the lens. These features tend to increase the thickness of the resultant lenses and compromise wearing comfort and physiological acceptability.

Moreover, conventional toric lens designs require a large number of stock keeping units in inventory (the total number of different prescriptions which are maintained in stock and can be prescribed) in order to fit a broad astigmatic patient base. For example, current Frequent Replacement Toric lens products are available in 800 stock keeping units per base curve in inventory (40 spherical powers×2 cylindrical powers×10 different cylindrical axis placements). Such a large number of stock keeping units per base curve in inventory is uneconomical to produce and maintain, particularly for a disposable modality product. The required large number of stock keeping units in inventory arises primarily from the need to provide 10 or more different cylindrical axes placements. Furthermore, any significant misalignment of the cylindrical axis with respect to the cylindrical axes of the eye normally results in a significant loss of visual acuity.

In an attempt to reduce the required number of cylindrical axis placements in stock keeping units, Australian Published Patent Application WO 93/03409 combines aspherical surfaces with toric surfaces to accommodate axial misalignment through the increased depth-of-focus provided by aspheres. The use of an aspheric surface enhances the depth-of-field of toric lenses and minimizes the effect of rotational misalignment of the toric lenses. Complex optics such as diffraction optics using echelets or birefringence optics are also disclosed by this published patent application. One disadvantage in using this prior art approach is the difficulty in manufacturing and controlling such complex optics and aspheres. Additionally with aspheric optics, patient anatomical variations have been shown to produce compromised visual acuity. In summary, this prior art approach is undesirable because of the high level of visual unpredictability of aspheric optics on the real world patient base, and because of the difficulty in manufacturing and controlling aspheric and other complex optics.

SUMMARY OF THE INVENTION

Accordingly, it is a primary object of the present invention to provide concentric annular ring lens designs for astigmatic patients which reduce the sensitivity of the patient to toric axis misalignment, thus reducing the required number of stock keeping units maintained in inventory for a toric product. The present invention provides toric lens designs which reduce the number of cylindrical axis placements required to fit astigmatic patients relative to conventional toric lens designs.

Some embodiments of the present invention eliminate a toric surface, prism ballast and slab-off features, and provide spherical optical powers at the basic prescription Rx spherical power, the cylindrical power prescription Rx, and an intermediate optical power between the spherical and cylindrical optical powers.

A further object of the subject invention is the provision of concentric annular ring lens designs for astigmatic patients which comprise a multifocal concentric annular ring design on either the front or back surface and a toric curve on the reverse surface to correct for astigmatism.

The present invention uses alternating concentric annular rings to divide the optical zone of a contact lens into regions having at least two optical powers, a first optical power corresponding to the refractive spherical component of a patient's basic prescription Rx, and a second optical power corresponding to the cylindrical power of a patient's basic prescription Rx, or a portion thereof.

The present invention provides enhanced and improved visual acuity for astigmatic patients by using concentric annular ring lens designs for the correction of low levels of astigmatism, and also can selectively utilize aspheric curves to enhance vision for higher amounts of astigmatism.

In accordance with the teachings herein, the present invention provides a multifocus, concentric annular ring lens for astigmatic patients wherein one of the front and back surfaces of the lens defines a toric curve, and the other surface defines a plurality of spherical concentric annular rings having at least one first spherical annular ring corresponding to the patient's basic distance spherical prescription Rx, and at least one second spherical annular ring corresponding to the patient's basic cylindrical prescription Rx, such that the multifocus toric lens is rotationally desensitized because of the enhanced depth-of-field provided by the plurality of concentric annular rings.

In greater detail, the difference between the optical powers of the first and second spherical annular rings is preferably less than 2.00 diopters. The second spherical annular ring(s) corresponds to a portion of the full cylindrical prescription Rx. The design can also incorporate third spherical annular ring(s) corresponding to an intermediate optical power which is between to the optical powers of the first and second annular rings. The concentric annular rings surround a central disc having the patient's basic spherical