CONTACT LENS WITH REDUCED SPHERICAL ABERRATION FOR APHAKIC EYES

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to contact lenses and, more particularly, to aspheric contact lenses with conicoid optical surfaces for aphakic eyes. (In the aphakic eye, the crystalline lens has been removed for medical or other reasons leaving the remainder of the eye intact.)

2. Description of the Prior Art

Contact lenses are of particular importance for aphakic persons because they obviate the necessity for heavy spectacles that are unattractive and uncomfortable. Conventional hard and soft plastic contact lenses with spherical optical surfaces suffer from spherical aberration (where peripheral rays come to focus in front of the paraxial image surface). In particular, those lenses in the 12.5 diopter to 15.5 diopter range—generally the correction power range needed for aphakic persons—have short front surface radii (of approximately 5.9 to 7.0 mm), which can lead to severe misfocusing of peripheral rays. Despite the short front surface radii, it is not likely that spherical aberration would be detected in bright surroundings (the pupil diameter stop would be small so that aberrations would be minimal). However, because of such short front surface radii, spherical aberration would be detectable easily at moderately low light levels and could reduce visual acuity dramatically when the wearer is driving at night or is watching television in a darkened room. In the latter case, for example, with a pupil diameter of less than 6 mm, the aphakic eye might see a fuzzy disk of nearly 1.5° diameter surrounding every distant point source of light in the field of view. Assuming the threshold of human visual acuity to be slightly above 0.01°, it is obvious that such an effect is not trivial.

There have been proposals for various contact lens designs characterized by one or more aspheric surfaces. In one case, the contact lens has an ellipsoidal rear surface that is intended to provide an improved fit to the cornea (which normally has an aspheric surface), but, when combined with a short radius front spherical surface, suffers from even greater spherical aberration than conventional lenses. In another case, as exemplified in British Pat. No. 620,852, accepted Mar. 31, 1949, a contact lens for the aphakic eye necessarily would be characterized by at least one non-conicoidal surface (represented by a fourth degree expression, i.e. a Cartesian oval surface of revolution). In still another case, as exemplified in U.S. Pat. No. 3,482,906, issued Dec. 9, 1969, the proposed combination of conicoidal front and rear surfaces are not intended to control spherical aberration, and consequently the combinations of front and rear optical surface eccentricities are different from those of the present invention.

SUMMARY OF THE INVENTION

The primary object of the present invention is to provide, particularly for aphakic eyes, contact lenses in the 10.0 to 18.0 diopter range, which are characterized by improved control of spherical aberration, based upon a novel relationship between a rear conicoidal optical surface that is fitted to the cornea and a prolate ellipsoidal front optical surface of needed power. The relationship between the front and rear surfaces is a

polynomial of at least third order, in which the eccentricity E_1 (a dimensionless quantity) of the front surface and the eccentricity E_2 (a dimensionless quantity) of the rear surface are related as follows:

$$E_1=[A+B(E_2)+C(E_2)^2+D(E_2)^3];$$

and in which A, B, C, and D have critical, empirically derived values that will be specified below.

Other objects of the present invention will in part be obvious and will in part appear hereinafter.

The invention accordingly comprises the product, together with its parts and their interrelationships, which are exemplified in the present disclosure, the scope of which will be indicated in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

For a fuller understanding of the nature and objects of the present invention, reference is made to the following detailed description, which is to be taken in connection with the accompanying drawings wherein:

FIG. **1** is a cross-sectional view of a contact lens, in association with depicted portions of an aphakic eye and in relation to incident and refracted rays of light;

FIG. **2** illustrates geometrical principles, by which the present invention is characterized;

FIG. **3** illustrates further geometrical principles, by which the present invention is characterized; and

FIG. **4** is a graph containing curves illustrating certain principles in accordance with the present invention.

DETAILED DESCRIPTION OF CERTAIN FEATURES OF THE FIGURES

Generally, FIG. **1** illustrates a contact lens **20**, which is located operatively on the cornea **24** of an aphakic eye. It will be observed that this eye has no crystalline lens, the iris being shown at **26** and the retina, at the paraxial focal surface, being shown at **28**. Contact lens **20**, which ranges from 10.0 to 18.0 diopters in strength, is characterized by the following:

(1) a front surface **30**, of designated vertex radius of curvature R_1;

(2) a rear surface **32**, of designated vertex radius of curvature R_2;

(3) a thickness **34**, designated t;

(4) an axial ray at 36;

(5) a peripheral ray at **38**;

(6) a point A, at which axial ray **36** intersects paraxial focal surface **28**;

(7) a point B, at which peripheral ray **38** intersects axial ray **36**;

(8) a point C, at which peripheral ray **38** intersects paraxial focal surface **28**;

(9) a paraxial focal length **40**, extending from a second nodal point **42** to paraxial focal surface **28**;

(10) a paraxial back focal length **44**, extending from a point **46** to paraxial focal surface **28**;

(11) transverse spherical aberration **48**, designated H'_R;

(12) a longitudinal spherical aberration **50**, designated LA'hd R;

(13) L_1 = the standard distance to an object, taken as −6096mm (approximately 20 feet);

(14) Y_1 = the height of ray **38** as it strikes front surface **30**, taken as 3 mm when determined by iris **26** in a darkened environment;

(15) A semi diameter **52**, of the optical surface.