CONTACT LENS HAVING AN INDEX OF REFRACTION APPROXIMATING THAT OF HUMAN TEARS

BACKGROUND OF THE INVENTION

Although known and used for some years, contact lenses have not achieved full acceptance by most members of the public having vision difficulties requiring correction. Contact lenses of the scleral type cover a substantial area of the eye during use, thereby sealing off circulation of tears and the atmosphere. This causes partial asphyxiation which affects the metabolism and vision of the eye. The more recent corneal lenses, because of their relatively smaller size and lighter weight, usually cause less irritation to the cornea, and have achieved greater acceptance. However, the "break-in" period necessary to accustom the cornea of the wearer to support a corneal lens, while varying from person to person, depending upon the individual's sensitivity of the cornea, usually extends over a considerable period of time. Some persons have found contact lenses to be intolerable because of the eye irritation resulting during and after any extended period of continuous wear.

Effort has been made to design both scleral and corneal lenses to fit more comfortably. For example, U.S. Pat. Nos. 2,240,157-Gagnon et al. and 2,330,837-Mullen, suggest methods for producing a scleral lens in which the scleral band fits the contour of the eye of the wearer. However, the corneal portion of the lens clears the cornea and limbus, so that the lens never contacts the cornea when worn. Such lenses have generally required the use of an accessory fluid in the space between the cornea and the ground-out corneal area of the lens. Application of such lenses to the eye is difficult and painful, and they have not achieved wide popularity.

It has been suggested that eye irritation could be reduced by designing the contact lenses with various radii of curvature. U.S. Pat. No. 2,544,246-Butterfield suggests that the corneal lens have an inner spherical central area and an outer marginal portion formed by a series of separate and distinct steps to introduce a parabolic fit. U.S. Pat. No. 2,510,438-Tuohy, discloses a contact lens having a radius of curvature on its concave side slightly greater than the radius of curvature of the cornea, with an increasing clearance at the marginal areas of the lens. Feinbloom U.S. Pat. No. 3,227,507 discloses the production of a corneal contact lens having an inner ellipsoidal surface. While lenses disclosed in the foregoing patents offer an improvement over scleral type lenses, they nevertheless tend to cause considerable irritation to the eye, and on the average cannot be worn in excess of ten hours.

Use of softer material in the production of contact lenses to provide a more comfortable lens has also been suggested. U.S. Pat. No. 3,228,741-Becker discloses the use of a filler, transparent, hydrocarbon substituted polysiloxane rubber as a contact lens material. Lenses of this material are said to possess a softness similar to that of the upper lid of the human eye, a high permeability to carbon dioxide, oxygen, and water vapor, and an index of refraction ranging from 1.49 to 1.56, depending upon the amount of filler material used. Because of their soft, elastic characteristics, such materials do not lend themselves to consistent production of high quality contact lenses, nor are they dimensionally stable.

Wichterle et al. U.S. Pat. No. 3,220,960, discloses a hydrogel material consisting of from 20 to 90 percent of an aqueous liquid, and a cross-linked hydrophilic polymer. However, lenses made of such materials are handicapped by optical problems. Notably, the effective power of the lens changes as it is worn. Also, such lenses may be torn easily while in the hydrated state, or broken in the dehydrated state, thus adding a handling problem to their use. Moreover, such porous hydrogels are receptive to bacterial invasion and proliferation. Despite assertions to the contrary, it has been found that such hydrogel materials do not afford extended periods of comfortable wear in a high percentage of cases. An excellent discussion of the disadvantages of such lenses is found in Precision-Cosmet Digest, Vol. 5, No. 9, Apr. 1965.

Due to the limitations of the foregoing materials, contact lenses in commercial use at this time are almost universally manufactured from polymethyl methacrylate, an optically clear, moldable, synthetic polymer material characterized by an index of refraction of 1.49. However, as a result of the problems noted above in producing a lens which fits comfortably, lenses made from polymethyl methacrylate can be worn only for relatively limited periods of time.

It is therefore a primary object of the invention to provide an improved contact lens.

Another object of the invention is to provide a contact lens which affords a comfortable fit, and which may be worn for extended periods of time without causing irritation to the eye.

Yet another object of the invention is to provide a contact lens having an index of refraction approaching that of human tears.

A further object of the invention is to provide a contact lens whose posterior surface conforms with the anterior surface of the human cornea and/or sclera.

It is still another object of the invention to provide a contact lens which significantly diminishes the aberrations due to reflected light occurring with conventional contact lenses of the prior art.

SUMMARY OF THE INVENTION

It has now been discovered that contact lenses which can be worn comfortably over extended periods of time are attained if a wettable lens is fabricated from a transparent, dimensionally stable, solid material characterized by an index of refraction approximating that of the human tears. This may be achieved in accordance with one aspect of the present invention by providing a contact lens of such a material in which the posterior surface of the lens conforms with the varying topography of the anterior segment of the human cornea and/or sclera.

The present invention takes advantage of the fact that differences between the indices of refraction on either side of an interface of a given curvature will result in a refractive or vergence power change at this interface depending upon the curvature and the indices of refraction. The refractive indices of the synthetic polymer materials most widely used as contact lenses vary from a low of 1.49 to a high of about 1.55. However, the total or combined index of refraction of the eye as an optical instrument averages to about 1.3375, or almost equal to that of the human tears (1.336).

The significant difference between the index of refraction of the eye and that of the material of which present lenses are composed limits the number of modifications or so-called fitting curves which may be placed on the posterior aspect of the lens before the optical quality of the lens is impaired. Thus, when contact lenses made of a material having a higher index of refraction than the cornea are modified excessively within the optical zone of the lens, the resulting aberration due to the difference between the indices of refraction will significantly alter the visual acuity. This is particularly true in the case of flush-fitting therapeutic lenses where the curvature markedly departs from sphericity.

It has now been discovered that by using a transparent, dimensionally stable, solid material, characterized by an index of refraction approximating the index of refraction of the human tears and "workable" to the extent that it can be either molded or ground into a lens, any number of fitting curves or modifications can be made on the posterior aspect of the lens in order to give the best lens-corneal relationship and thus provide the optically perfect lens. The only optical requirement of lenses made in accordance with the invention is that the front surface of the lens be characterized by a curve of such power necessary to correct the refractive error of the eye. In air, lenses of the invention are aberrated when the anterior surface is spherical and the posterior surface is aspherical or irregular, *i.e.*, conforms with the varying topography of the anterior segment of the human cornea and/or sclera. How-