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INTRAOCULAR LENS FOR PATIENTS WITH CENTRAL RETINAL DEGENERATION.

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Description

The invention relates to an intraocular lens (IOL) for use in combination with an external lens system to form an image on the retina. The leading cause of blindness in America is macular degeneration. In this condition, the central retina, which perceives fine detail, is deficient. In the less severe cases of this disease, patients can often be helped by simple magnifiers or by various telescopes, both of which serve to enlarge the image formed on the retina.

Magnifiers are used for reading or other tasks involving near vision. A variety of magnifiers are available and are generally useful for their intended purpose. However, such magnifiers are bulky and inconvenient and are of no help in other tasks such as walking about. Such magnifiers are likewise tiring to the user, thus detracting from their usefulness.

For improved distant vision, a telescope is required. In order to be suitable for low vision patients, telescopes must be compact, light weight, and reasonably inexpensive. These requirements together with basic optical limitations generally result in a device which magnifies but with an enormous loss of visual field. For the low vision patient, with his natural lens, telescopes of 2.2×, 2.5×, or 3× are often prescribed for use outdoors, or for other distance viewing. The field loss is so great that most patients with macular degeneration do not find telescopes of much practical value. Such telescopes are, therefore, often of limited practical use because of their narrow field, poor cosmetic appearance and difficulty in fitting to the patients face. As a result, they are used relatively infrequently by patients.

When patients have cataracts in addition to macular degeneration, the prognosis is even worse. Removal of the cataract, followed by vision correction with spectacles or contact lenses, renders the field of vision smaller without significantly improving magnification.

The aphakic patient with a normal retina faces a formidable optical problem. Spectacle lenses of +11—+16 diopters are needed to provide the required additional focusing power. Alternatively, contact lenses of similar power may be worn. For those who cannot wear contact lenses and must, therefore, wear spectacles, the lenses are thick and must be precisely fitted to the patient's face. Furthermore, the field of view is restricted by the refracting effect of the lenses. Alternatively, contact lenses of similar power may be worn. However, a substantial number of patients, particularly older patients with limited finger dexterity, cannot wear contact lenses.

If the aphakic patient further has macular degeneration, the conventional telescopic low-vision aids mounted on the spectacle frame will be a problem. The telescope adds weight, and projects beyond the already large spectacle lenses. The telescope further limits the field of vision. The field problem is aggravated by the fact that the presence of the spectacle lens moves the telescope yet further from the eye than the optimum position.

Some aphakic low-vision patients can use a 6× or 8× hand-held telescope. The 6× has a field of view of 11°, while the 8× has a field of 8°. Yet, this solution is not viable for the many patients who do not have the steadiness of hand to use such hand-held telescopes.

As a result of the above optical problems and the already reduced visual acuity, low-vision patients who develop cataracts are often not operated on.

Conversely, in other instances demagnification of the optical image is desirable. Thus, patients with retinitis pigmentosa (RP) and some patients with advanced glaucoma suffer a loss of peripheral vision. In order to function normally, e.g., to cross the street, they may benefit from a visual aid that demagnifies the retinal image, thus putting more of the visual field onto the central portion of the retina that is still functional.

The principle of the invention and the various embodiments disclosed herein overcome the above deficiencies while achieving the objectives set forth.

A search of the prior art has uncovered the following materials:

TROUTMAN, in an article entitled “Artificial and Artificial Aniseikonia”, which appeared in the American Journal of Ophthalmology, pages 500—509, October, 1963, discusses the state of the art in artificial intraocular lenses. On page 614, the article states: “There is no reference in the literature on intra-ocular lenses as to the telescopic magnification which can be attained with the combination of an intraocular lens and a spectacle lens.”

LEVY, Jr. et al., U.S. Patent 4,074,368, disclose an intraocular lens that is based on the principle of a Galilean telescope wherein both the negative element 18 and the positive element 14 are fastened together, and both placed within the eye. Positive element 14 is an air lens formed by bubble 15, and negative element 18 is an air lens formed by bubbles 20 and 22. The patent suggests implantation of this intraocular lens system for relief of conditions such as macular degeneration and diabetic retinopathy.

LIEB, U.S. Patent 3,834,023, discloses anterior chamber lenses for refractive correction of aphakia, high astigmatism, and anisometropia, and bilateral and unilateral cataracts. Of particular interest are Figs. 6—9, wherein lens 20 is of the diverging type.

FILDERMAN, U.S. Patent 3,027,803, discloses a spectacle lens-contact lens system which forms a modified Galilean telescope. Contact lens 10 serves as the negative lens in the telescope lens system, and central segment L2 of spectacle lens L1 serves as the positive objective lens of the telescope lens system.

Furthermore, the patent discloses how a 2× magnification system can be developed by using a negative
lens of -50 diopters and a positive lens of +25 diopters.

DITTMER, U.S. Patent 2,164,801, discloses a corrective lens system wherein an alternate embodiment provides a telescopic lens system, as illustrated in Fig. 5. The telescopic lens system comprises negative contact lens 23 which is worn on eye 10, and positive spectacle lens 24 which is mounted in front of eye 10.

SPERO, U.S. Patent 2,078,590, discloses telescopic spectacles wherein positive lens 15 is secured to glass carrier member 16, and negative lens 17 is secured to second glass member 18. The total lens system is secured to a spectacle lens mounting system.

ISEN, in "Feinbloom Mini-Scope Contact Lens" as reported in the Encyclopaedia of Contact Lens Practice (November 15, 1961), teaches making a Galilean lens system out of a doublet constructed contact lens. As can be seen, the negative lens is placed closest to the eye, while the positive objective lens is placed a small distance away from the eye.

FR—A—1 103 399 (see in particular Figs. 11 and 14) and an article by J. Boberg-Ans in Brit. J. Ophthal. (1961) 45, 37-43 (see e.g. cases 5 and 9) also describe the implantation of intraocular implants in the anterior chamber of the eye. These disclosures are concerned with correction of aphakia not with the provision of magnification of the retinal image with a wide field of vision.

It is an object of the invention to overcome the above disadvantages associated with conventional devices and techniques, and to provide a system allowing for improved vision with a greater field of vision than was previously possible.

In accordance with the invention a negative-powered intraocular lens is sized and shaped for implantation in the posterior chamber of an eye and has a power of substantially -10 to -100 diopters so as to provide magnification of the retinal image and a wide field of vision when used in combination with an external positive lens.

Preferably, the lens is provided with flexible support members for positioning the lens in the posterior chamber of the eye.

The invention also provides an optical system comprising a negative-powered intraocular lens as described above and a positive external lens, whereby the intraocular lens and the external lens in combination provide, in use, magnification of the retinal image and a wide field of vision.

The external lens may be a positive spectacle lens, contact lens or Fresnel lens.

Fig. 1 is a cross-sectional view of one embodiment of an optical system of the invention;

Figs. 2A and 2B are front and side magnified cross-sectional views of the negative intraocular lens shown in Fig. 1;

Figs. 3A and 3B illustrate cross-sectional views of the intraocular lens inserted in the posterior chamber;

Fig. 4 is a graph comparing the magnification and field of vision of various optical systems, including the system of the invention;

Fig. 5 is a graph used for selecting the correct intraocular lens, depending upon the magnification desired.

As was noted above, most broadly, the optical system of the invention includes an intraocular lens, such as is illustrated in Figs. 1 and 2. Referring to Fig. 1, the negative power of the intraocular lens is selected such that, when a spectacle lens or contact lens of appropriate power is worn, the patient will have a magnified retinal image.

As was noted previously, the intraocular lens may be used in combination with either a contact lens and/or a spectacle lens. When combined with a spectacle or contact lens of a positive power, the combination will behave as a Galilean telescope with a magnification factor greater than unity.

As seen from Fig. 1, a spectacle lens 7 having a positive refracting power is worn in combination with the negative intraocular lens 9 so as to focus the image on the retina 11. The intraocular lens is positioned behind the iris.

It is an advantage of the invention that the intraocular lens is positioned close to the pupil of the eye, thereby permitting the lens to be of relatively small size, as compared, for example, with negative-power contact or spectacle lenses which might otherwise be used for the same purpose. Additionally, by positioning the lens in the posterior chamber, maximum separation is achieved between the spectacle or contact lens used and the intraocular lens, thereby achieving maximum magnification.

The distance, v, shown in Figure 1 is the vertex distance, defined as the separation between the vertex of the cornea and the vertex of the spectacle lens. As will be explained below, this distance is important in determining the magnification that is achieved.

The general intraocular lens structure contemplated is of the type which is generally known, such as, for example, the type disclosed in United States Patent 4,041,552 to GANIAS, the disclosure of which is hereby incorporated by reference.

As may be seen from Figs. 2A and 2B, the intraocular lens is provided with loops or haptics 13 of plastic or metal for holding the lens element 15 firmly in position. Fig. 2B illustrates relative dimensions in millimeters. The clear aperture (CA) in this example is 4.5 mm.

Fig. 3A shows one possible technique for positioning the lens in the posterior chamber of the eye. As illustrated, the haptics 13 expand by spring tension, contacting the inside surface of the capsule 15. In Figure 3B, the situation is illustrated in which the capsule has been removed, as in an intracapsular extraction. In this case the loops 13 expand against the ciliary body 17 and thereby position the IOL. The
loops are shown as being inclined with respect to the plane of the IOL, the purpose being to position the IOL in a posterior position thus providing added separation between the IOL and the exterior lens. The decision as to the type of IOL to use may be made at the time of surgery.

Naturally, in this embodiment, the intraocular lens and the spectacle and/or contact lens must be appropriately selected so as to provide the desired degree of magnification, and a sharply focused retinal image, while providing optimal field of vision.

The power, P, of the IOL can be calculated from the equation:

$$P = \frac{n}{g-b} \frac{nv + g(l-vC)}{nv + b(l-vC)}$$

where

- \( n \) = index of refraction of the intraocular media = 1.336
- \( g \) = distance from cornea vertex to the retina (Fig. 1) in meters (m).
- \( b \) = distance from cornea vertex to the IOL (m)
- \( v \) = vertex distance of spectacle lens (m)
- \( C \) = power of cornea, in diopters
- \( F \) = focal length of normal (phakic) eye
- \( M \) = magnification desired

Once the power of the IOL has been determined from Equation 1, the power, S, of the spectacle lens can be found as follows:

$$S = -\frac{P(g-b)}{\frac{n}{g-b} (n-bC) - n(n-gC)} \frac{P(g-b)}{\frac{n}{g-b} (n-b-nv) + n(nv + g-vgC)}$$

S is the power required for distant vision. If correction is needed for near vision, appropriate additional power can be added to S.

The field of view is defined with the help of Fig. 6. The total angular field is defined as the angle \( \alpha \).

$$\tan \frac{\alpha}{2} = \frac{d}{2} \left( \frac{1}{F + k} - S \right)$$

where

- \( d \) = diameter of spectacle lens (m)
- \( v \) = vertex distance from spectacle lens to the cornea (m)
- \( k \) = distance from cornea vertex to nodal point of the eye (m). For the normal eye \( k = .007 \text{m} \).
- \( S \) = power of spectacle lens, in diopters.

Practically speaking, the procedure for selection of the appropriate lenses may be as follows. The patient’s requirements for magnification and field of view are determined from a detailed examination, including visual acuity, if possible, and from determination of the patient’s visual needs, e.g., distance vision vs. reading. From the available negative IOLs, the power that best meets the patient’s requirements is selected. A graph such as that illustrated in Figure 4 may be used for this purpose. The intraocular lens will have a power of -10 to -100 diopters with lenses of -40 diopters to -100 diopters being very suitable. After the implant surgery, when the eye has stabilized sufficiently, the patient is refracted to determine the best spectacle (or contact lens) for optimum vision.

The spectacle lens can be of the conventional glass or plastic type. It is also possible to use a positive Fresnel lens in some cases, in order to reduce the weight of the spectacle. These lenses consist of thin plastic on which circular sections of a lens have been embossed. The finished piece acts as a lens, but the total thickness is much less than the conventional lens. They are especially useful in situations requiring large positive (or negative) dioptric powers.

Fig. 4 illustrates the magnification and field of view obtainable for the various IOL powers indicated in parentheses. For purposes of illustration, a fixed diameter of spectacle lens, 40 mm, was assumed. If a smaller diameter spectacle lens, or a spectacle lens that is not round is used, the field will be different from that shown. Also illustrated in Fig. 4 are the magnification and field obtainable in a number of currently available telescopic low vision aids, such as the biotic, and the “designs for vision” wide angle telescope.

It is apparent that for any given magnification up to 2.5X, the combination of IOL plus spectacle lens yields a wider field of view than the conventional telescopic low vision aids.

Curve B in Fig. 4 illustrates the magnification and field obtainable with the combination of a contact lens (CL) and a spectacle lens. Since it is impractical to utilize contact lenses of extreme negative power, the curve is extended only to -30 D. Curve B indicates that the magnification obtainable with this combination is quite limited. Comparison with curve A shows that for a given magnification, the field obtainable with the IOL/spectacle combination is superior to that of the CL/spectacle combination.

Figure 5 is a graphic representation of the relation between IOL power and magnification for various combinations of IOL and external lenses. Line A gives the magnification as a function of IOL power for the combination of an IOL and a spectacle lens located at a vertex distance of 13 mm (v = .013 m) from the cornea. This vertex distance is typical for many patients. Each figure in parentheses is the required power
of the external lens, the spectacle lens in this case. Line B is for the combination of an IOL together with a contact lens. It is apparent that this combination does not offer the degree of magnification that can be obtained with the IOL/spectacle combination. The reason is that the IOL and the CL are of necessity in fairly close proximity, as dictated by the anatomy of the eye. Line C is for the more complex combination of an IOL, a contact lens of ~20 D power, and a spectacle lens. This arrangement increases the magnification available compared to either of the above combinations. The price to be paid for this additional magnification is the inconvenience of wearing a contact lens as well as a spectacle lens, and the increased power necessary in the spectacle lens. Additional 10 mm of vertex distance is seen to give a significant increase in magnification compared to line A. There are two implications to this observation. First, a given magnification can be achieved with a lower power IOL and lower power spectacle lens if the vertex distance can be somewhat greater than the standard 13 mm. Second, and perhaps more important, after an IOL has been in place for a few years, the patient may require increased magnification, due to progressive macular degeneration. Rather than risk a second operation to replace the IOL, the patient can be fitted with spectacles having a greater vertex distance. For example, if the IOL were a ~20 D lens, the initial magnification for a vertex distance of 13 mm would be 1.97X. Later the magnification could be increased to 2.5X by increasing the vertex distance to 23 mm, together with an appropriate change in the power of the spectacle lens. While an increase in vertex distance does create minor problems in fitting spectacle lenses and in cosmetic appearance, the disadvantages are less objectionable than the traditional telescopic or hand-held telescopes.

As seen from the information provided by the graphs, the system of the invention provides improved magnification and increased field of vision over systems which are commonly available, while being easier to use and being far more cosmetically acceptable. As was noted previously, it is a significant advantage of the invention that, for a given magnification, the intraocular lens-spectacle combination provides a larger field of view than any of the alternatives shown in Fig. 4. Additional advantages of the inventive combination are lighter weight, and fewer optical elements to be maintained in alignment. Cosmetically, a simple lens in front of the eye, even a strong positive lens, is less objectionable than a telescope mounted on the spectacle frame, as is presently employed.

The advantages of a system providing a wide field of view are obvious. A wide field greatly increases the ability of the patient to move about, to avoid obstacles, and generally to function normally, and therefore, provides a viable alternative to systems which have been proposed previously.

As has been noted above, the intraocular lens may be used in combination with a contact lens instead of a spectacle lens. The negative intraocular lens and positive contact lens once again act to form a Galilean telescope. However, this embodiment is less preferred by virtue of the shorter spacing between the two lenses, as compared with the spacing between the intraocular lens and a spectacle lens. The magnification which is obtained is, therefore, quite limited and fixed, as a result of the anatomy of the eye.

In yet another embodiment of the invention, a negative contact lens may be used in combination with a negative intraocular lens and a positive spectacle lens to satisfy the parameters set forth previously. However, by virtue of the extra problems associated with contact lenses wear, as well as the additional problems of alignment of the three lenses, this system is likewise less preferable than the simple intraocular lens-spectacle lens system.

An additional embodiment of the invention employs a positive contact lens in combination with a positive spectacle lens and a negative intraocular lens. By dividing the required positive power between the spectacle lens and the contact lens, the power of the spectacle lens can be reduced, thus reducing its weight and improving the cosmetic appearance. Furthermore, for a given magnification, the field of view is somewhat greater for the combination including the positive contact lens than for the spectacle/IOL combination. Although the invention has been described with respect to particular materials, lenses, and intraocular lens systems, it is to be understood that the invention is not limited to the particulars disclosed, but extends to all equivalents falling within the scope of the claims.

Claims

1. A negative-powered intraocular lens characterised in that the lens (9) is sized and shaped for implantation in the posterior chamber of an eye and has a power of substantially ~10 to ~100 diopters so as to provide magnification of the retinal image and a wide field of vision when used in combination with an external positive lens (7).

2. An intraocular lens as claimed in claim 1, wherein the lens is provided with flexible support members (13) for positioning the lens in the posterior chamber of the eye.

3. An intraocular lens as claimed in claim 1 or 2, wherein the lens has a negative power of substantially ~40 to ~100 diopters.

4. An optical system comprising a negative-powered intraocular lens (9) as claimed in any one of the preceding claims and a positive external lens (7), whereby the intraocular lens (9) and the external lens (7) in combination provide, in use, magnification of the retinal image and a wide field of vision.

5. An optical system as claimed in claim 4, wherein the external lens (7) is a positive spectacle lens.
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6. An optical system as claimed in claim 4, wherein the external lens is a positive contact lens.
7. An optical system as claimed in claim 4, wherein the external lens is a positive Fresnel lens.
8. An optical system as claimed in claim 4, and further comprising a second external lens, wherein the first external lens is a positive spectacle lens, and the second external lens is a negative contact lens.
9. An optical system as claimed in any one of claims 4 to 8, wherein the intraocular lens (9) has a magnification of up to 2,5× in use with the external lens (7).

Patentansprüche

1. Intraokularlinse mit negativer Vergrößerung bzw. Brennstärke, dadurch gekennzeichnet, daß die Linse (9) in Größe und Form der Implantation in die hintere Augenkammer angepaßt ist und eine Brennstärke von im wesentlichen −10 bis −100 Dioptrien aufweist, um eine Vergrößerung des Netzhautbildes und ein breites Sehfeld zu liefern, wenn sie in Kombination mit einer äußeren positiven Linse (7) verwendet wird.
2. Intraokularlinse nach Anspruch 1, worin die Linse mit flexiblen Abstützteilen (13) versehen ist, um die Linse in der hinteren Augenkammer zu positionieren.
3. Intraokularlinsen nach Anspruch 1 oder 2, worin die Linse eine negative Brennstärke von im wesentlichen −40 bis −100 Dioptrien aufweist.
4. Optisches System, das eine Intraokularlinse (9) mit negativer Vergrößerung bzw. Brennstärke nach einem der vorstehenden Ansprüche und eine positive äußere Linse (7) umfaßt, wodurch die Intraokularlinse (9) und die äußere Linse (7) bei Verwendung in Kombination eine Vergrößerung des Netzhautbildes und des Sehfeldes liefern.
5. Optisches System nach Anspruch 4, worin die äußere Linse (7) ein positives Brillenglas ist.
6. Optisches System nach Anspruch 4, worin die äußere Linse eine positive Kontaktlinse ist.
7. Optisches System nach Anspruch 4, worin die äußere Linse eine positive Fresnellinse ist.
8. Optisches System nach Anspruch 4, das weiterhin eine zweite äußere Linse umfaßt, wobei die erste äußere Linse ein positives Brillenglas und die zweite äußere Linse eine negative Kontaktlinse ist.
9. Optisches System nach einem der Ansprüche 4 bis 8, worin die Intraokularlinse (9) bei Verwendung mit der äußeren Linse (7) eine Vergrößerung des bis zu 2,5-fachen aufweist.

Revendications

1. Lentille intraoculaire de vergence négative, caractérisée en ce que ladite lentille (9) présente des dimensions et une forme adaptées pour son implantation dans la chambre postérieure d’un œil et possède une divergence d’environ −10 à −100 dioptres, de manière à procurer un grossissement de l’image rétinienne et un large champ de vision quand elle est utilisée en combinaison avec une lentille externe de vergence positive (7).
2. Lentille intraoculaire selon la revendication 1, caractérisée en ce qu’elle est pourvue de moyens flexibles de retenue (13) pour son maintien en position dans la chambre postérieure de l’œil.
3. Lentille intraoculaire selon l’une des revendications 1 ou 2, dans laquelle ladite lentille présente une divergence d’environ −40 à −100 dioptres.
4. Système optique comprenant une lentille intraoculaire de vergence négative (9) comme revendiquée dans l’une quelconque des revendications précédentes et une lentille externe de vergence positive (7), de telle sorte que la lentille intraoculaire (9) et la lentille externe (7) utilisées en combinaison, procurent un grossissement de l’image rétinienne et un large champ de vision.
5. Système optique selon la revendication 4, dans lequel la lentille externe (7) est une lentille de lunettes de vergence positive.
6. Système optique selon la revendication 4, dans lequel la lentille externe est une lentille de contact de vergence positive.
7. Système optique selon la revendication 6, dans lequel la lentille externe est une lentille de Fresnel de vergence positive.
8. Système optique selon la revendication 4, comprenant en outre une deuxième lentille externe, dans lequel la première lentille externe est une lentille de lunettes de vergence positive, et la seconde lentille externe est une lentille de contact de vergence positive.
9. Système optique selon l’une des revendications 4 à 8, dans lequel la lentille intraoculaire (9) a un grossissement jusqu’à 2,5 fois lorsqu’elle est utilisée avec la lentille externe (7).
FIG. 4.

FIELD, DEGREES

0  1.0  1.5  2.0  2.5  3.0
MAGNIFICATION

(-10) o (0) o (-10)
(-20) o (-20)
(-30) o (-40)
(-60) o (-80) o (-100)

H BIOPTIC I
V

H BIOPTIC II
V GALILEAN
H BIOPTIC 3X
WIDE ANGLE

CURVE A
IOL + SPECTACLE LENS
(CA = 40mm)

CL + SPECTACLE LENS
(CURVE B)