

PROBLEM THE INVENTION ATTEMPTS TO SOLVE

[0010] ~~Embodiments of t~~The present invention ~~was created with the~~
~~circumstances noted above as the background, and its object is to~~ provide an
intraocular lens of a novel structure and the manufacturing method thereof that is able
5 to effectively improve quality of vision (QOV), as well as being easy to apply to
patients and having a high level of practicality.

MEANS FOR SOLVING THE PROBLEM

[0011] ~~The present invention provides an intraocular lens manufacturing~~
~~method including (a) an optical characteristics setting step of setting in an optical~~
10 ~~portion a spherical aberration of a size corresponding to a coma aberration remaining~~
~~in a human eye of a patient from which a human lens was extracted, and of a size for~~
~~which the spherical aberration remaining in that human eye of that patient will not be~~
~~offset and will be made to remain; (b) a lens shape setting step of determining a lens~~
~~shape of the optical portion wherein the spherical aberration set at the optical~~
15 ~~characteristics setting step is provided as a corrective optical characteristic for a~~
~~residual irregular astigmatism in that human eye of that patient; and (c) a lens forming~~
~~step of forming an intraocular lens having optical characteristics in which a high-order~~
~~aberration of that optical portion is rotationally symmetrical around an optical axis, by~~
~~means of forming the optical portion to have the lens shape determined by the lens~~
20 ~~shape setting step. According to a first aspect, there is provided an intraocular lens~~
~~manufacturing method comprising: an optical characteristics setting step of setting in~~
~~an optical portion a spherical aberration of a size corresponding to a coma aberration~~
~~remaining in a human eye of a patient from which a human lens was extracted, and of~~
~~a size for which the spherical aberration remaining in that human eye of that patient~~
25 ~~will not be offset and will be made to remain; a lens shape setting step of determining~~
~~a lens shape of the optical portion wherein the spherical aberration set at the optical~~
~~characteristics setting step is provided as a corrective optical characteristic for a~~
~~residual irregular astigmatism in that human eye of that patient; and a lens forming~~
~~step of forming an intraocular lens having optical characteristics in which a high-order~~
30 ~~aberration of that optical portion is rotationally symmetrical around an optical axis, by~~
~~means of forming the optical portion to have the lens shape determined by the lens~~
~~shape setting step.~~

[0011a] According to a second aspect, there is provided an intraocular lens comprising: an optical portion being set with a spherical aberration as a corrective optical characteristic for a residual irregular astigmatism in a human eye of a patient, the spherical aberration being of a size corresponding to a coma aberration remaining in the human eye of the patient from which a human lens was extracted, and of a size for which the spherical aberration remaining in that human eye of that patient will not be offset and will be made to remain, wherein a high-order aberration of the optical portion is rotationally symmetrical around an optical axis, wherein the spherical aberration set for the optical portion has an RMS value that satisfies both of the following formulas: intraocular lens spherical aberration $\geq$ Coma aberration remaining in the eye after lens extraction $- 0.37 \mu\text{m}$; and intraocular lens spherical aberration $\leq$ Coma aberration remaining in the eye after lens extraction $- 0.17 \mu\text{m}$.

[0012] From the start, the intraocular lens of embodiments of the present invention has a prerequisite of allowing coma aberration to remain in the eye of the patient, and in regards to this point, is completely different from the concept of prior art corrective lenses like that in Patent Document 1 which has the object of eliminating high-order aberration as much as possible. Then, on top of that, by actively giving spherical aberration of a size corresponding to the coma aberration to the intraocular lens, the decrease in QOV due to coma aberration is reduced.

[0013] Specifically, embodiments of the present invention ~~are~~^{is} focused on coma aberration among the high-order aberrations when improving vision, and in fact does not give corrective optical characteristics that offset the coma aberration, but rather is based on new knowledge of improving vision by giving spherical aberration of a size corresponding to the coma aberration as the corrective optical characteristic. In other words, it is not possible to avoid design and manufacturing being extremely difficult for improving vision as long as it is based on the prior art concept of simply achieving zero by offsetting all or specific high-order aberrations in order to suppress a decrease in vision due to high-order aberration as noted in Patent Documents 1 and 2 described previously. In contrast to this, focusing on the coma aberration which has a big adverse effect on vision, embodiments of the present invention ~~are~~^{is} established on a novel technical concept that is completely different from the past, which is to reduce the adverse

effect due to coma aberration which is not rotationally symmetrical in relation to the optical center axis, by using spherical aberration which is rotationally symmetrical in relation to the optical center axis. In particular, with this embodiment of the present invention, the spherical aberration given to the lens used as the corrective optical characteristic is nothing more than an optical characteristic corresponding to the coma aberration, and therefore it goes without saying that it does not achieve zero by offsetting the coma aberration, and it does not achieve zero by offsetting spherical aberration, either. It should be understood that this is technology of a completely different perspective from that of the past, which makes having coma aberration and spherical aberration remain be something affirmative.

[0014] In fact, by setting spherical aberration in the intraocular lens, being able to effectively deal with coma aberration which has a large adverse effect on QOV has a large significance when manufacturing or handling intraocular lenses, when doing surgery or the like, which are implementations of embodiments of the present invention. Specifically, with a focus only on coma aberration, to give wave aberration of the reverse code to the coma aberration, a complex lens surface shape that is rotationally asymmetrical must be given to the intraocular lens, and not only is the design and manufacturing thereof extremely difficult, but when inserting into the eye as well, it is necessary to have precise alignment in the circumference direction, so this is not practical. In contrast to this, the intraocular lens for which spherical aberration is set according to embodiments of the present invention is formed having optical characteristics that are rotationally symmetrical around the optical axis, so it is not necessary to specify a position in the circumference direction such as during the manufacturing process or when inserting in the eye, so manufacturing and handling are easy, which makes it easy to put this to practical use.

[0015] In other words, in addition to finding that it is possible to reduce the decrease in QOV due to coma aberration by using spherical aberration, focus was placed on being able to perform setting of spherical aberration in the intraocular lens with the intraocular lens optical characteristics left being rotationally symmetrical, and an embodiment of the present invention was completed by combining these with each other. Then, if an embodiment of the present invention which was completed based on this kind of novel basic concept is followed, it became possible to provide a novel intraocular lens which can reduce the decrease in QOV due to coma aberration which is one type of high-order aberration for which a practical countermeasure was extremely difficult in the past, and to give good QOV, while being sufficiently practical in terms of manufacturing and implementation.

[0016] With embodiments of the present invention, to deal with the decrease in QOV due to coma aberration remaining in the human eye from which the human lens was extracted, the fact that it is effective to actively give spherical aberration using the

intraocular lens has been objectively confirmed by comparison between examples and comparative examples in the embodiment described later. When examined by the inventor of the present invention, at least the subjective focal depth is made deeper by giving spherical aberration, and it is thought that this is an item for which one technical basis is acknowledged. In particular, the QOV improvement effect exhibited by the intraocular lens according to embodiments of the present invention is also clear from the example data described later.

[0017] However, the spherical aberration with the intraocular lens of embodiments of the present invention is set at a size corresponding to the coma aberration, and if the coma aberration is large, then large spherical aberration is set, and if the coma aberration is small, then small spherical aberration is set. Here, the specific correlation of the setting value of the spherical aberration of the intraocular lens in relation to the coma aberration remaining in the eye of the patient can be determined considering not only objective optical characteristics of the patient's eye, but also subjective vision preferences of the patient or the like.

[0018] For this kind of determination method, a device that can easily measure the spherical aberration for not only the lens optical system but also the human eye optical system is disclosed in Japanese Patent No. 4652558, the specification of U.S. Patent No. 7,078,665 and the like, and for example since the OPAL 300 (product name) made by Spot Optics Corp. is available on the market as a wave aberration measurement device using the Shack-Hartmann Method, a person skilled in the art could implement this easily. In particular, when determining the value of the spherical aberration corresponding to the coma aberration with the eye optical system, it is not necessary to match both items, as described above. For example, even when dealing with contact lenses or glasses, prescription is ultimately left to the subjective vision sense of the user, or is selected based on consideration of the application. From this point of view, determination of the value of the spherical aberration should be handled by the person skilled in the art by referencing the user's opinion, the eye optical system objective measurement information or the like. Thus, compared to the prior art structure contact lenses as noted in Patent Documents 1 and 2, for example, implementing embodiments of the present invention does not involve an impractical level of difficulty. Of course, with embodiments of the present invention, to make it possible to more easily and quickly determine the spherical aberration, it is effective to further narrow the selection range of the spherical aberration, and from that objective, it is preferable to use the optical characteristics selection technology given by the formulas and the like noted hereafter.

[0019] Specifically, with the human eye, even in a state with the human lens extracted, there are cases when there is spherical aberration due to the shape of the cornea and the like, for example. In that case, the spherical aberration set for the intraocular lens of embodiments of the present invention is designed considering the spherical

[0025] Also, embodiments of the present invention provides an intraocular lens for which the spherical aberration of a size corresponding to the coma aberration remaining in the human eye of a patient from which the human lens has been extracted, and of a size for which the spherical aberration will not be offset and will be made to remain in the human eye of that patient is set for the optical portion as the corrective optical characteristic for residual irregular astigmatism in the human eye of that patient, and for which the high-order aberration for the optical portion is rotationally symmetrical around the optical axis.

[0026] As is clear from the description above, the intraocular lens with this kind of structure can give good QOV to patients, and in fact the design and manufacturing can be realized easily, so it is easy to provide on the market and put to practical use. The intraocular lens of this kind of structure according to embodiments of the present invention is preferably manufactured using the method of embodiments of the present invention described above. Also, each preferred mode noted in the description of the manufacturing method above can be applied to the intraocular lens of embodiments of the present invention as long as it is structurally feasible.

[0027] Also, with the intraocular lens of embodiments of the present invention, it is preferable that at least one of the spherical aberration value set according to the method of the present invention as described above or the RMS value is displayed on at least one of the lens main unit, its individual package, the housing package or the housing box.

EFFECT OF THE INVENTION

[0028] If embodiments of the present invention ~~areis~~ followed, the QOV is improved by applying spherical aberration, which is an optical characteristic that is rotationally symmetrical around the optical axis, in relation to coma aberration having a big adverse effect on QOV and for which it is difficult to realize an intraocular lens having optical characteristics that offset the coma aberration. Accordingly, it is possible to realize an intraocular lens of a novel structure for which design, manufacturing, and handling are easy, and practical usability is excellent.

BRIEF DESCRIPTION OF THE DRAWINGS

[0029]

FIG. 1 is a front view showing an intraocular lens as one embodiment of the present invention.

FIG. 2 is a vertical cross section explanatory view of a human eye in which the intraocular lens shown in FIG. 1 is inserted.

FIG. 3 is a graph for explaining the change with aging of the spherical aberration of the cornea in the human eye.

FIG. 4 is a graph for explaining the change with aging of the coma aberration of the cornea in the human eye.

FIG. 5 is a simulation optical image showing the vision during application to