

Usefulness of an aspheric vitreous contact lens in eyes implanted with an aspheric intraocular lens for internal limiting membrane peeling

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Objective: To report the usefulness of aspheric vitreous contact lens (AVCL) for internal limiting membrane (ILM) peeling in aspheric intraocular lens (AIOL) implanted eyes.

Methods: In an AIOL-implanted Gullstrand eye model, ray tracing was used to calculate spherical aberration, modulation transfer function (MTF) and grating pattern in the entire eye, including the vitreous contact lens (VCL), which was either a spherical VCL (SVCL) or an AVCL. Under VCL displacement and tilting of the eye, MTF and grating pattern were compared.

Results: Compared with SVCL and AVCL, the spherical aberration was $-1.419 \mu\text{m}$ and $0.02 \mu\text{m}$, respectively; MTF was 34% and 65%, respectively. The AVCL was compared with the SVCL under the following conditions: decentration, 0.2 mm; tilt, $<2.0^\circ$; and tilt of light to eye axis, $<2.5^\circ$. MTF was higher, and the center of the visual field in the grating pattern was clearer.

Conclusions: AVCL facilitates ILM peeling in an AIOL-implanted eye more easily than does SVCL, although special care should be taken in the AVCL positioning and eye tilt.

Key words: internal limiting membrane peeling, spherical aberration, vitreous contact lens, aspheric intraocular lens, modulation transfer function

Abbreviations: AIOL, aspheric intraocular lens; AVCL, aspheric VCL; ILM, internal limiting membrane; MTF, modulation transfer function; SIOL, spherical intraocular lens; SVCL, spherical vitreous contact lens; VCL, vitreous contact lens

Introduction

Aspheric intraocular lenses (AIOLs) with negative spherical aberration have been developed to offset positive spherical aberration of the cornea and reduce or eliminate spherical aberration of the entire eye. In eyes implanted with AIOLs, spherical aberration at a pupil diameter of 6 mm is significantly decreased, and night contrast improves;¹⁻³ therefore, AIOLs are now preferred in most cataract operations.

In AIOL implanted eyes, when using a vitreous contact lens (VCL) during internal limiting membrane (ILM) peeling procedure, authors have seen poorer fundus visualization than in eyes implanted with a spherical intraocular lens (SIOL). The material of the AIOL was the same as the SIOL (refractive index 1.413, silicon lens).

Based on this experience as a clue, we hypothesized that the difference of spherical aberrations in the entire eye, including the VCL, would change the results. Therefore, we thought that in order to increase the resolution, spherical aberrations in the entire eye, including the VCL, should be reduced, and increasing the modulation transfer function (MTF) is an important concurrent objective.

Subjects and Methods

In a Gullstrand eye model, at a pupil diameter of 6 mm, we evaluated fundus visualization using a VCL in eyes implanted with a KS-3Ai AIOL (refractive index 1.413, silicon lens, optic diameter, 6 mm; effective optic diameter, 5.2 mm; power, 23.5 diopters; STAAR Japan, Tokyo). After the IOL was implanted into an eye, aspheric

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aberration of the entire eye approaches 0.

Optical simulation was performed with a Zemax-EE (ZEMAX Development Corporation, Bellevue, WA, USA) with ray tracing (Figure 1). The spherical aberration and MTF of the entire eye, including the VCL, were calculated.

We used a Zubora type I spherical vitreous contact lens (SVCL) (refractive index 1.490, acrylic lens for posterior pole surgery; optic diameter, 10 mm; Sun Contact Lens, Kyoto) and an aspheric VCL (AVCL) that we designed, by modifying the anterior surface of the Zubora type I SVCL to minimize spherical aberration of the entire eye, including VCL, and maximize MTF, at 100 cycles/mm in the eye implanted with the KS-3Ai IOL.

With optical simulation, the light point source from

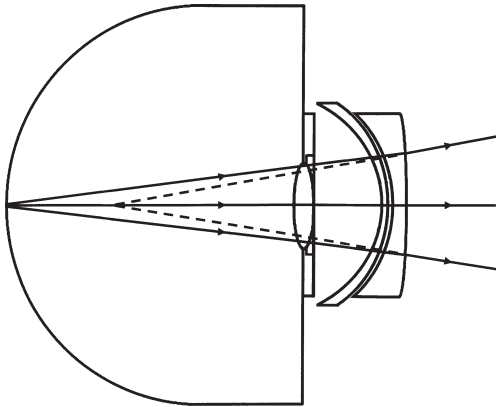


Figure 1. Ray tracing using Zemax for optical simulation

The light-point source from the retina is scattered by the VCL, and the focal point appears as a virtual image. This focal point is set as the eye point observed by microscopy and used to calculate spherical aberration and MTF.

the retina is scattered by the VCL, and the focal point appears as a virtual image. This focal point is set at the eye point observed during microscopy, and the spherical aberration and MTF are calculated. A viscous substance is applied to the cornea to fix the VCL, and this viscous substance is always present between the eye and the VCL. The refractivity of this viscous substance is 1.33, the same as water. We calculated the spherical aberrations of the entire eye (eye + VCL) in this environment.

To evaluate fundus visualization during vitreous surgery in an AIOL implanted eye, we simulated a grating in the visual field when the posterior pole (about a 5×5 mm area of fundus) was viewed during detailed surgery, e.g., ILM peeling. To evaluate fundus visualization with VCL decentration or eye tilting, both of which occur during surgery, various parameters, including VCL decentration from the center of the eye, the tilt angles of the eye, and the optic axis were varied. In an AIOL-implanted eye, the characteristics of the MTF and of the grating were calculated for the SVCL and the AVCL. Good visualization conditions for the AVCL were also calculated. MTF is shown as data with components that are parallel and vertical to the direction of VCL displacement. Data were plotted on the assumption that visualization by surgeons approximates an average value that is calculated by adding the vertical and parallel components and by then dividing the sum by two.

Results

Compared with SVCL and AVCL, the spherical aberration, of the entire eye, including the VCL, was $-1.419 \mu\text{m}$ and $0.02 \mu\text{m}$, respectively. Compared with SVCL and AVCL, the MTF, of the entire eye, including

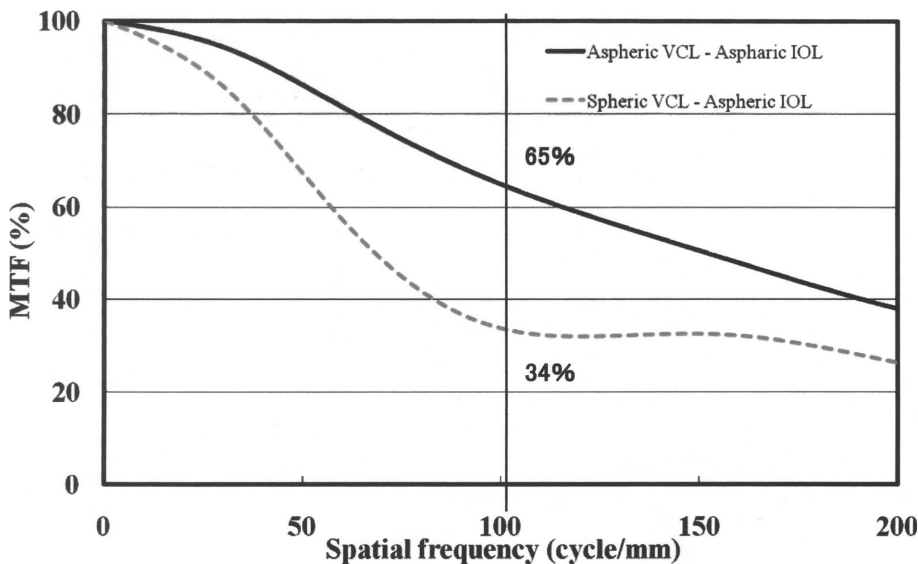


Figure 2. MTF for SVCL in an AIOL eye and AVCL in an AIOL eye, in which MTF was 34% for the SVCL but increased to 65% for the AVCL (pupil diameter, 6 mm at 100 cycles/mm).

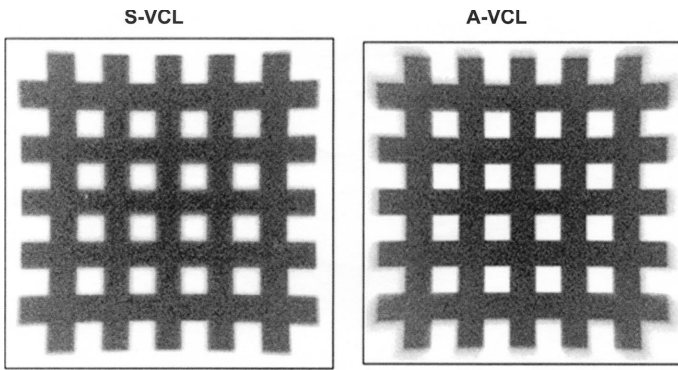


Figure 3. Fundus visualization in an AIOL-implanted eye (5×5 mm)

For optical simulation of fundus visualization during surgery, this image is simulated in an AIOL-implanted eye with a 5×5 mm grating on the retinal surface at the posterior pole, using an SVCL and AVCL, as viewed through a microscope. With the AVCL, compared with the SVCL, the grating was clearer with higher resolution in the central field of vision. However, the AVCL showed greater distortion and loss of resolution in the far periphery compared with the SVCL.

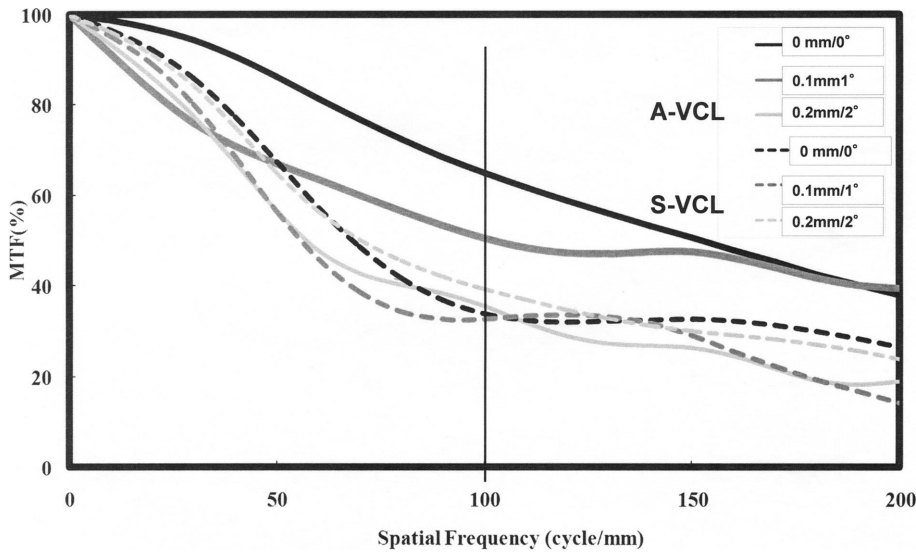


Figure 4. Changes in MTF due to tilt and decentration of VCL

Solid lines indicate the aspheric contact lens, and the dashed lines indicate the spherical contact lens (pupil diameter 6 mm, 100 cycles/mm).

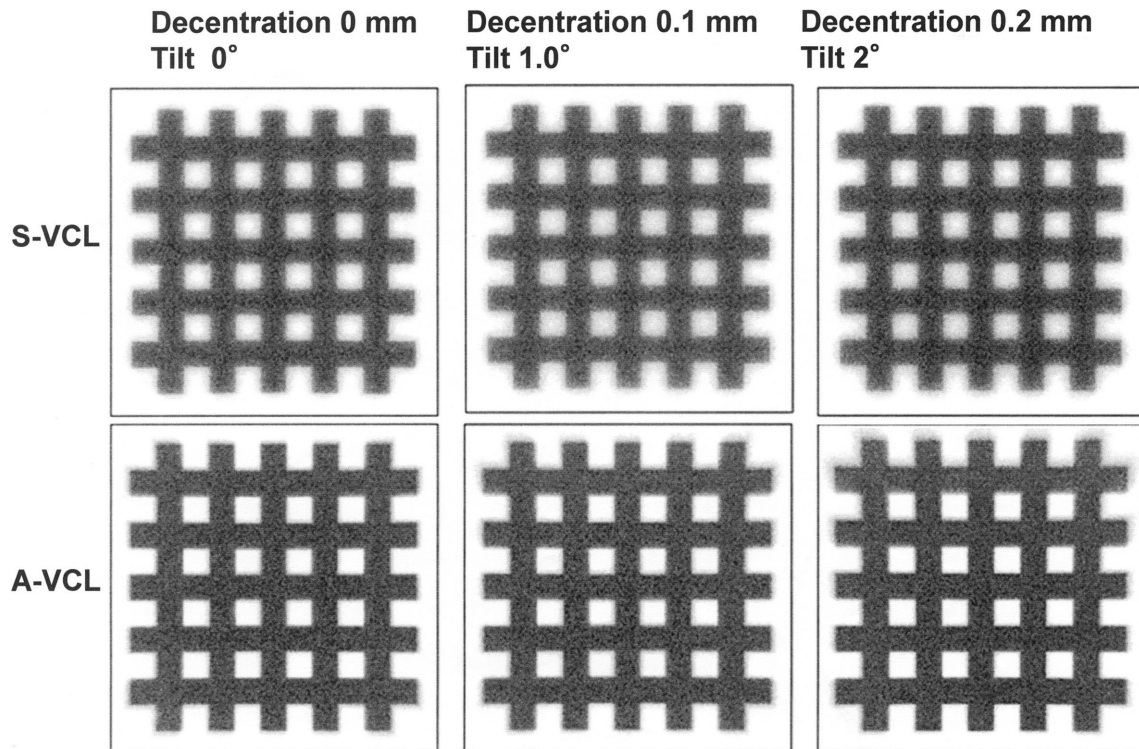


Figure 5. Changes of grating image due to tilt and decentration of VCL (5×5 mm)

Top row: the spherical contact lens in use; bottom row: the aspheric contact lens in use (pupil diameter 6 mm).

the VCL, was 34% and 65%, respectively (pupil diameter 6 mm, 100 cycles/mm) (Figure 2). Using the AVCL, the center of the grating in the AIOL eye was clearer than when the SVCL was used. However, distortion gradually increased towards the periphery, and at the periphery itself, visualization was clearer with the SVCL (Figure 3). With a VCL decentration of 0.2 mm and a tilt of $<2^\circ$, as well as a $<2.5^\circ$ tilt of the axis of the light, the AIOL eye showed higher MTF values with the AVCL than with the

SVCL. The percentage decrease in MTF values was higher with the AVCL than with the SVCL (Figures 4, 5). In the images obtained under the above conditions, the central area was clearer with the AVCL than with the SVCL (Figures 6, 7).

Discussion

There have been some recent reports on the validity of

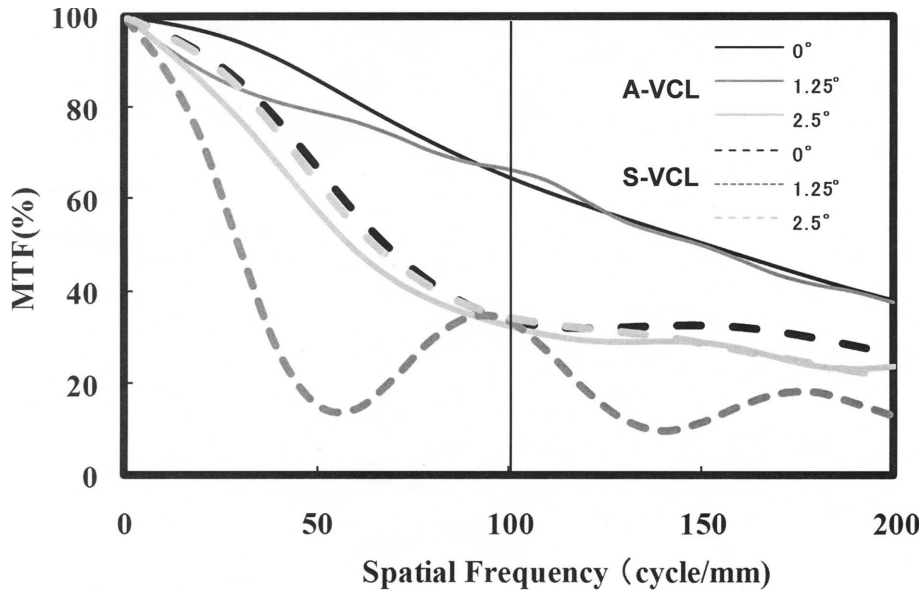


Figure 6. Changes of MTF due to eye tilting

Solid lines indicate the aspheric contact lens, and dashed lines indicate the spherical contact lens (pupil diameter 6 mm, 100 cycles/mm).

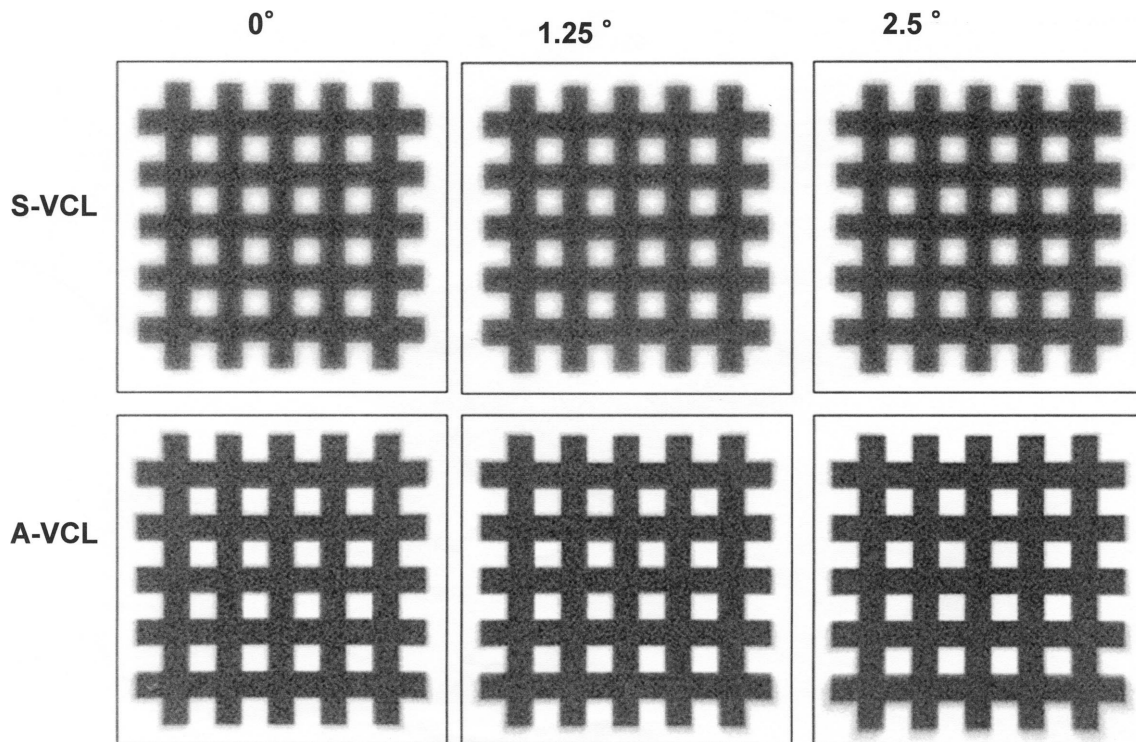


Figure 7. Changes of grating image due to eye tilting (5×5 mm)

Top row: a spherical contact lens in use; and bottom row: an aspheric contact lens in use (pupil diameter 6 mm).

ILM peeling; which is, however, due to these ILMs being so delicate, transparent, and because they could not be recognized easily, the acquisition of techniques for this procedure would not be simple. For the ILM peeling procedure, the operation starts with visual recognition of ILM followed by the removal of the affected parts; but when visibility recognition of ILM became difficult at the initial stage, then the ILM peeling procedure could not be performed. Whether or not the surgeon can accurately perform the initial peeling of the ILM procedure without retinal hemorrhage and retinal break will be the key to successful operations.

In order to visually recognize the ILM and enhance the surgical technique more easily, ILM peeling was reported using a similar substance to indocyanine green to stain the membrane area³; but the fact remains that even when the area is stained, delicate surgical maneuvering and skills are required to complete the procedure successfully. Moreover, because of the retinal toxicity concern,⁴ the substance should not be used; but if the substance has to be used, it should only be used in low concentrations. In order not to use or to limit the use of indocyanine green, good central resolution is required.

There is less spherical aberration in the AIOL-implanted eye than in the SIOL-implanted eye, so differences in contrast vision can occur with pupil dilation at night. Similar spherical aberration effects are expected in vitreous surgery, which is also performed with mydriasis.⁵⁻⁷ Furthermore, because a concave lens is placed on the cornea to visualize the fundus during vitreous surgery, spherical aberration of the VCL must be considered in addition to spherical aberration of the eye.

The MTF is the 2-dimensional spatial frequency response for light-dark contrast. This indicates the extent to which various fine stripes, including color-contrasted stripes, can be perceived,⁸ and is suitable for quantitative evaluation of fundus visualization during vitreous surgery. Compared with SVCL and AVCL, the spherical aberration of the entire eye, including the VCL, was $-1.419 \mu\text{m}$ and $0.02 \mu\text{m}$, respectively, while that of the MTF was 34% and 65%, respectively. Therefore, using AVCLs provides better central visualization than does using SVCLs. The MTF indicates resolution at only one central point. During vitreous surgery, however, the entire fundus must be visualized, not just a single central point. We, therefore, used a computer image of a 5×5 mm grating as the

image of the entire posterior pole of the fundus during vitreous surgery, especially ILM peeling in the case of an AIOL implanted eye. Optical simulation with the AVCL, compared with the SVCL, showed better central resolution but poorer peripheral resolution.

From these results of simulation, clinical use of our simulated AVCL, rather than the Zubora type I SVCL, would facilitate ILM peeling in 23.5-diopter KS-3Ai AIOL-implanted eyes, although special care should be taken in AVCL positioning and eye tilt to ensure good central resolution. This theory is based on simulation data under certain conditions. In actual clinic settings, central resolution would change due to the various fluctuations in the eye, e.g., aqueous depth, axial length of eye, and the power of the implanted IOLs. Further clinical investigations in the appropriate use of AVCLs are warranted.

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