Observation of Peripheral Retina by Topical Endoscopic Imaging Method—A Preliminary Study

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ABSTRACT

Introduction: This study evaluated the usefulness of rigid endoscopy placed on the corneal surface to observe the peripheral retina.

Methods: The authors studied 15 eyes in 15 patients (12 men, 3 women; mean age 55.9 years; range 22–74 years) that underwent vitreous surgery at the Department of Ophthalmology at Saga University Hospital. With patients in a supine position, after topical anesthesia, an eye cup was placed between the eyelids and filled with hydroxyethyl cellulose solution and physiologic saline. With a rigid endoscope placed near the corneal surface, the target areas were then observed and recorded. The usefulness of rigid endoscopy to observe the

peripheral retina was evaluated based on differences due to lens status and pupil size.

Results: In seven aphakic eyes, irrespective of pupil size, the peripheral retina could be observed up to the entire ora serrata (all quadrants). In eight eyes implanted with an intraocular lens, the observable area changed with pupil size and anterior capsulorrhexis size.

Conclusion: This technique using rigid endoscopy was simple to manipulate and useful for observing and recording the peripheral retina. In particular, in aphakic eyes, irrespective of pupil size, the retina could be observed to the ora serrata.

Keywords: Aphakic eyes; Intraocular lens; Peripheral retina; Proliferative retinopathy; Retinal detachment; Rigid endoscopy; Topical endoscopy fundus imaging; Vitreous surgery

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INTRODUCTION

The basics of ophthalmic evaluation include detailed observation and recording of intraocular findings. Among retinal diseases, marked advances have been made in observing macular lesions, and testing can be performed

rapidly and noninvasively [1, 2]. However, to observe the peripheral retina, particularly near the ora serrata, testing depends on the skill of the examiner; for example, by slit-lamp microscopy using a contact lens with a depressor, or binocular indirect ophthalmoscopy using scleral depression [3–5]. Slit-lamp microscopy is difficult in children and patients who have difficulty sitting, and with binocular indirect ophthalmoscopy, differences in diagnostic ability among examiners are substantial, and saving the findings as image recordings is difficult.

Guyomard et al. [6] observed animal eyes and reported topical endoscopy fundus imaging (TEFI) using a rigid endoscope. Using this technique, the iridocorneal angle and peripheral retina in small animals, which have previously been difficult to observe and record, can now be visualized. Hirata and Okinami also reported its usefulness for imaging retinal findings in rabbit eyes and as an observation system during surgery [7]. In the present study, the authors modified this technique and investigated its clinical usefulness for postoperative retinal evaluation in patients with retinal detachment and proliferative retinopathy (proliferative vitreoretinopathy, proliferative diabetic retinopathy), in whom examination of the peripheral retina is necessary.

METHODS

Patients

This study included 15 eyes in 15 patients (randomly selected; 12 men, 3 women; mean age 55.9 years; range 22–74 years) that underwent vitreous surgery at the Department of Ophthalmology at Saga University Hospital.

The underlying disease requiring surgery was rhegmatogenous retinal detachment (seven eyes), proliferative vitreoretinopathy (six eyes), and proliferative diabetic retinopathy (two eyes). Lens status was aphakia (seven eyes) and intraocular lens (IOL) implantation (eight eyes). The study protocols were approved by the Clinical Research Ethics Committee at Saga University. Patients were given a full written explanation about the usefulness of this technique and potential complications, and each provided written informed consent.

Modified Method of Topical Endoscopic Observation

For observation of the peripheral retina using the rigid endoscope, the authors modified a previously reported method [6, 7]. The rigid endoscope system was similar to that reported previously. For this study, the authors used a 6.0 cm × 4 mm (outer diameter) rigid endoscope for otoscopic use (1215AA; Karl Storz, Tuttlingen, Germany). The tip has a crescent-shaped light and is used by connecting it to a xenon light source (Xenon Nova 175; Karl Storz, Tuttlingen, Germany). The endoscope was connected to a digital camera utilizing a 400,000-pixel charge-coupled device (CCD) image sensor unit (Telecam-C and Telecam DXII; Karl Storz, Tuttlingen, Germany), and was connected to a monitor.

Although the xenon light source used in this study is widely used in clinical settings, this equipment is not adjusted for ophthalmic use. Therefore, the authors determined an acceptable power of light (below the maximum permissible exposure $\cong 1 \text{ mW/cm}^2$) using a xenon light source used in a standard vitrectomy. As a control, the spectral irradiance

Fig. 1 Spectral irradiance of the xenon lamp used in this study and that used for a standard vitrectomy as a control. *Purple* spectral irradiance of the control xenon light source (Xenon BrightStar illumination system; DORC, Zuidland, The Netherlands) at maximal strength equipped with a 420 nm cut-off filter. *Light blue* 80% of maximal strength of the control light source. *Blue* 50% of maximal strength of the control light source. *Green* spectral irradiance of the xenon light source used in this study (Xenon Nova 175; Karl Storz, Tuttlingen, Germany). The strength of the light was adjusted not to exceed the peak of that at 50% of the control xenon light source. *Red* spectral irradiance of the xenon light source used in this study at the same setting as the *green* and with a 420 nm cut-off filter

of the xenon light source (Xenon BrightStar illumination system; DORC, Zuidland, The Netherlands) was measured using a spectroradiometer (USR-30; Ushio Inc., Yokohama, Japan) at a distance of 20 mm from the tip of the 23-gauge light pipe to the surface of the light receiving unit at 50%, 80%, and 100% of maximal strength equipped with a 420 nm cut-off filter (Fig. 1; blue, light blue, and purple, respectively). Then, in order to determine the appropriate condition for this study, the strength of the spectral irradiance of the xenon light source used in this study was adjusted not to exceed the peak of the light strength at 50% of the control xenon light source by turning the setting dial (Fig. 1; green). Moreover, a filter with a 420 nm cut-off filter

Fig. 2 Schematic diagram of the examination set-up. An eye cup is placed on the eye to be examined, and the cup is filled with hydroxyethyl cellulose solution and physiologic saline. The rigid endoscope is placed near the eye for observation. The image is displayed on a monitor and saved as a video. *CCD* charge-coupled device image sensor unit

(Sharp Cut Filter L42; Hoya Candeo Optonics, Toda, Japan) was attached to prevent the potential phototoxicity of the short-wavelength light (Fig. 1; red). The sum total examination time was set to less than 7 min for each examination. In addition, the absence of thermal injury of the cornea due to a temperature increase was confirmed beforehand by preliminary testing [7].

Patients were placed in the supine position on a bed, and topical anesthetic was instilled into the eye to be examined. In the eye to be examined, an eye cup for use with ultrasound biomicroscopy was placed between the eyelids and, to protect the corneal surface and to create an interface that would improve the quality of the image, the eye cup was filled with hydroxyethyl cellulose solution (Scopisol solution; Senju Pharmaceutical Co., Ltd., Osaka, Japan) and 1–2 mL of physiologic saline. The endoscope was placed in proximate contact with the cornea, and was directed such that the entire peripheral retina could be observed. In addition, while observing with a monitor, the image was recorded (Fig. 2).

The recorded data was downloaded to a computer, the necessary scenes were captured, and still images were prepared. Based on the acquired data, differences in the observable area of the peripheral retina were evaluated according to lens status and pupil size. Possible adverse events, such as damage of the corneal epithelium or discomfort during examination, were also recorded.

RESULTS

A total of 15 eyes in 15 patients were examined for observation of the peripheral retina in this study. No complications due to examination occurred in any patients. Due to observation of the peripheral retina alone, complaints of mild photophobia were seen in only two patients, and there were no

Table 1 Characteristics of the patients

Case	Age	Gender	Eye	Cause	Pupil size (mm)	Lens status; type of IOL	CCC size (mm)	Observable areas
1	70	F	R	PVR	Aniridia	Aphakia	N/A	Ora serrata in all quadrants
2	48	F	R	PDR	7.0	Aphakia	N/A	Ora serrata in all quadrants
3	74	M	R	PVR	5.5	Aphakia	N/A	Ora serrata in all quadrants
4	22	M	R	PVR	5.0	Aphakia	N/A	Ora serrata in all quadrants
5	74	M	L	PVR	5.0	Aphakia	N/A	Ora serrata in all quadrants
6	60	M	R	PVR	5.0	Aphakia	N/A	Ora serrata in all quadrants
7	37	M	L	RRD	4.5	Aphakia	N/A	Ora serrata in all quadrants
8	60	M	R	RRD	7.7	7 mm acrylic three-pieces	5	Ora serrata in all quadrants
9	51	M	L	RRD	7.0	7 mm acrylic three-pieces	5	Ora serrata (nasal), 3DD from equator (temporal)
10	72	M	R	RRD	6.0	6 mm acrylic one-piece	5	Ora serrata in all quadrants
11	65	M	R	RRD	6.0	6 mm acrylic three-pieces	5	Ora serrata (nasal), 3DD from equator (temporal)
12	69	F	R	RRD	6.0	6 mm acrylic three-pieces	4	3DD from equator in all quadrants
13	60	M	L	RRD	5.0	6 mm acrylic three-pieces	4	Ora serrata (nasal), 3DD from equator (temporal)
14	24	M	L	PVR	5.0	6 mm acrylic one-piece	4	2DD from equator in all quadrants
15	52	F	R	PDR	4.5	6 mm acrylic three-pieces	3.5	2DD from equator in all quadrants

CCC continuous curvilinear capsulorhexis, DD disk diameter, F female, IOL intraocular lens, L left, M male, N/A not applicable, PDR proliferative diabetic retinopathy, PVR proliferative vitreoretinopathy, R right, RRD rhegmatogenous retinal detachment

Fig. 3 Rigid endoscopic image of proliferative diabetic retinopathy in Case 2. **a** Observation in only one direction: the ora serrata and peripheral retina are clearly visualized. This demonstrates that retinal photocoagulation in the

periphery has been performed. **b** Composite photograph of endoscopic findings in entire periphery. Observation of the entire ora serrata is possible

Fig. 4 Anterior eye findings and rigid endoscopic image of retinal detachment due to giant retinal tear in Case 7. **a** Anterior eye findings: dilated pupil size of 4.5 mm. With examination of the retina by indirect ophthalmoscopy, the

most peripheral regions of the retina cannot be observed, and retinal photography is difficult. **b** Endoscopic findings: observation to the ora serrata is possible. Posttreatment findings of the causative tear can clearly be seen

patients in whom examination could not be performed.

In aphakic eyes (seven eyes), irrespective of pupil size, the entire ora serrata (all quadrants) could be observed (Table 1). By manipulating the endoscope, observation of the peripheral retina to the entire ora serrata was possible (Fig. 3). The observable area was unrelated

to pupil size; thus, examination of the postoperative course, for example, of rhegmatogenous retinal detachment from a tear in the ora serrata, was simple (Fig. 4).

On the other hand, among IOL-implanted eyes (eight eyes), the entire ora serrata could be confirmed in only two eyes. The observable areas changed based on pupil size, IOL

Fig. 5 Rigid endoscopic images of retinal detachment in Cases 9 and 10. **a** Endoscopic image in Case 9: from the edge of the intraocular lens (7 mm three-piece acrylic), visualization to the ora serrata is difficult, but the sites of treatment of the causative tear and subretinal fluid drainage

can be observed in detail. **b** Endoscopic image in Case 10: lateral to the edge of the intraocular lens (6 mm one-piece acrylic), the ora serrata can be seen. The retina below the lens capsule opacification is difficult to visualize, but by changing the direction of the endoscope, it can be observed

Fig. 6 Anterior eye findings and rigid endoscopic image of proliferative diabetic retinopathy in Case 15. **a** Anterior eye findings: dilated pupil size of 4.5 mm. Because of corneal opacification, with examination of the retina by indirect ophthalmoscopy, detailed visualization is not possible, and

retinal photography is difficult. **b** Endoscopic findings: with endoscopic observation of the retina through an area of transparent cornea, the peripheral retina, including photocoagulation spots, is observed

diameter, anterior capsulorrhexis size, and lens capsule opacification. In particular, because an opacified lens capsule greatly affected visibility, with larger capsulorrhexis size, observation to the periphery was possible (Fig. 5). However, in all cases, at a distance of 2–3 disk diameters from the equator,

the periphery could be observed (Table 1). Observation of causative tears and photocoagulation sites was possible in all cases. In addition, even in cases with corneal opacification, by viewing from a site without opacification, retinal observation was possible (Fig. 6).

DISCUSSION

This study investigated the usefulness of rigid endoscopy for examination of the peripheral retina. Due to the fact that the rigid endoscope permits wide-angle observation and a wide depth of field, manipulation is simple, and much information can be obtained. Compared with the existing procedures including slit-lamp microscopy using a contact lens with a depressor, or binocular indirect ophthalmoscopy using scleral depression, advantages of the examination procedure using rigid endoscopy include: (1) no need for slit-lamp microscopy; (2) no complex technique is required; (3) examination in patients unable to remain sitting is possible; (4) images can be recorded, and any images can be extracted; and (5) the apparatus is inexpensive [6–8].

In this study, with examination using a rigid endoscope, manipulation was simple, and the peripheral retina could be observed and recorded. In particular, in aphakic eyes, irrespective of pupil size, observation up to the entire ora serrata (all quadrants) was possible. For postoperative evaluation of retinal detachment patients, adequate observation is essential; not only of the causative tear, but also to assess any new breaks, or new break formation associated with traction of the retina due to residual vitreous. In diseases where more vitreoretinal traction is involved, including proliferative vitreoretinopathy and proliferative diabetic retinopathy; the recording of retinal changes over time is useful in judging the need for additional treatment and can lead to early detection of complications.

However, this method does have some limitations. Although not fully evaluated in the present study, in phakic eyes of elderly patients retinal translucency can decrease due

to light scattering from the examination light. Therefore, preoperative evaluation of the peripheral retina and causative tears in elderly and cataractous eyes seems difficult. Moreover, the possibility of phototoxicity and risk of corneal injury due to long-term observation may require further investigation.

CONCLUSION

Advances in endoscopes have led to improved resolution, less invasiveness, and greater functionality. To date, in the field of ophthalmology, endoscopy has been limited to fiber optic endoscopes used for insertion into the eye through scleral incisions during surgery [9], or used in lacrimal duct evaluation or treatment [10, 11]. This observation technique is a novel method in terms of looking into the eye from the corneal surface. In the future, with improved illumination systems, stereoscopic-vision rigid endoscopes, and image processing methods, the possibilities will greatly expand [12–14].

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Conflict of interest. The authors have no conflicts of interest to disclose.

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