Choices of Wide-angle Viewing Systems for Modern Vitreoretinal Surgery

A semi-quantitative evaluation of the visual angle field and imaging contrast.

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Wide-angle viewing systems (WAVs) are a useful fundus observation device for vitreous surgery, which been continually developed from the late 1980s to the present based on the indirect ophthalmoscopic principle.[1-9] The WAVs not only offer a panoramic view of the surgical field but also improve the safety and efficiency of the surgical procedures.[10,11] Surgeons can easily evaluate the fundus status and the location of retinal pathologies through the panoramic view, and engage the peripheral retina without requiring excessive rotation of the eyeball during surgery as was necessary when viewing the fundus through conventional floating prismatic lenses. In addition, the use of WAVs in conjunction with chandelier lighting allows easier bimanual maneuvers because these provide a view of the peripheral region without globe rotation, eliminating concerns regarding fragility of small-gauge instruments.[12] These tools may have played a part in the more widespread use of small-gauge vitrectomy for a variety of vitreoretinal pathologies, including challenging cases. At the same time, recently a variety of WAVs has been newly developed or upgraded from previous versions along with the recent widespread use of microincisional vitrectomy surgery (MIVS). Although the standard specification of each WAV such as the field angle of view is usually demonstrated in the brochures, the definition is often not identical among the manufactures. The optical design is the key industrial secret in each device, which will not be open to surgeons for comparison. In addition, the imaging quality (distortion) of the fundus view is not easy to quantitatively evaluate. Therefore, the differences of the viewing performances (field angle and imaging quality) have never been compared among the WAVs objectively. Here, we report a brief laboratory investigation for semi-quantitatively assessing the field angle of view and imaging quality of a grating target in a human model eye viewed through a variety of commercially available WAVs. The aim of this article is to provide the reader with comprehensive information of the latest advances in WAVs for modern vitreous surgery.

CONSTRUCTION OF A MODEL EYE FOR FUNDUS VIEWING EVALUATION

In the current study, we newly constructed a model eye that was originally made based on Gullstrand's model of the human eye for evaluating the fundus visualizing qualities through refractive and diffractive multifocal IOLs.[13] The body of the eye was made of metal, and the axial length was 24 mm (Figure 1A). The diameter of the pupil was 8 mm. The distance from the corneal anterior surface to the intraocular lens (IOL), if implanted, was 5 mm. The cornea was made of polymethylmethacrylate (PMMA). The anterior surface was aspheric, and the cornea was constructed to have a spherical aberration of 0.220 m, which is comparable to the mean value of human eyes with a pupil diameter of 6 mm. An angle scale for evaluat-

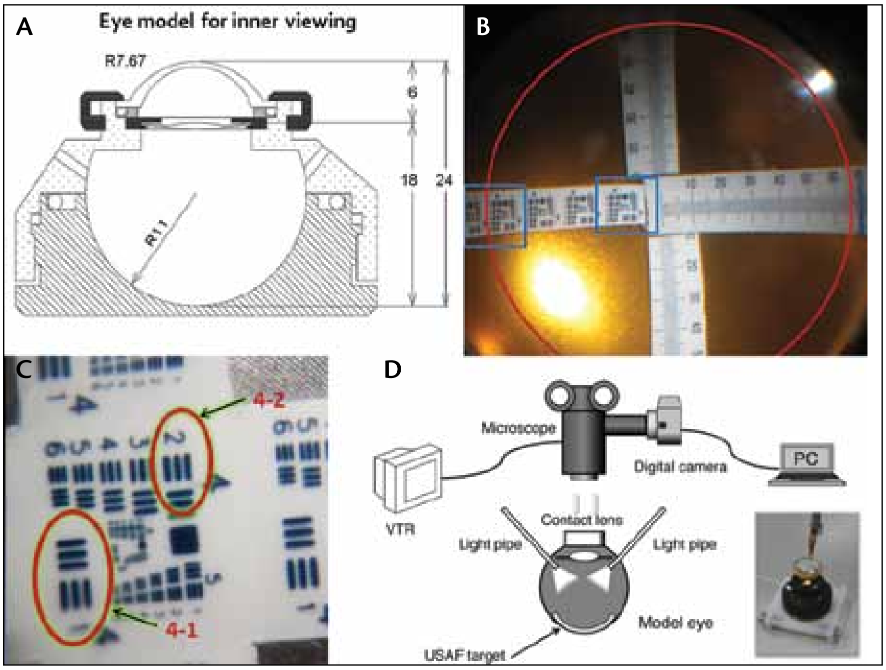

Figure 1. A schematic drawing of the model. The spherical aberration of the cornea is 0.22 m, which is comparable to the spherical aberration of human eyes (A). An intraocular lens is fixed in the aperture of the model eye. The angle scale and the USAF grating target are glued to the posterior surface of the model eye up to the peripheral retina (B). Contrast of grating viewed through wide-angle viewing systems can be converted to frequencies (cycles/mm) for statistical analyses (C). Schematic drawing overviewing the experiment procedures. Following the setting-up of each type of wide-angle viewing system, the target under chandelier endoillumination with xenon light source was photographed with a digital camera. The captured photo was used for semi-quantitatively measuring the angle of view and evaluating the differences in quality of the images (D).

ing the field angle of view and a 1951 United States Air Force (USAF) test target (Edmund Optics) were glued to the posterior surface of the model eye up to the periphery of the retina (Figure 1B). The USAF target consisted of gratings of different orientations and spatial frequencies (Figure 1C).[13] The model eye can be filled with balanced salt solution at room temperature or set under air conditioning for measurement.

FUNDUS IMAGING ANALYSES THROUGH WIDE-ANGLE VIEWING SYSTEMS

Using the eye model, we studied five noncontact type WAVs: BIOM (Oculus), Merlin (Volk Optical, Inc.), OFFISS (Topcon Medical Inc.), Resight (Carl Zeiss Meditec AG), and Peyman-Wessels-Landers semi-wide angle viewing system (Ocular Instruments), and two contact WAV lenses, Clarivit and HRX (Volk Optical, Inc.) (Figure 2). The image through a flat-concave contact lens made of quartz glass (HHV, Hoya) was used as control for assessing the image qualities at the posterior pole. The IOLs, if used, had the same spherical power of 20 D and were centered on the optical axis of the eye. The pupil size can be adjusted to either 8 mm or 4 mm in diameter by changing an artificial iris plate inserted in the anterior chamber. A 23-gauge wide-angled endoilluminating chandelier fiber connected to a xenon light source (Bright Star, Dutch Ophthalmic Research Center International BV) was inserted through the side of the model eye at positions similar to the sclerotomy sites used during pars plana vitreous surgery (Figure 1D). The angle scale and grating target were photographed with a digital camera (EOS Kiss X3; Canon Inc.) through a surgical microscope (Lumera T, Carl Zeiss Meditec) with 25.5x magnification (Figure 1D). To compare the field angle of view, the distance between the preplaced lens and the corneal surface of the noncontact type WAVs was adjusted to 3 mm, which is the minimal distance we could set for clinical use. To evaluate the differences in the quality of the images quantitatively, the contrasts of the gratings at the posterior pole and the equator were measured using Photoshop CS5 (Adobe). The contrast of gratings in the USAF test target can be converted to frequencies (cycles/mm) for statistical analyses (Table 1). The intensity at the center of the black stripe was set as Imax, and the intensity at the center of the white stripe was set at Imin. The contrast was calculated as (Imax – Imin)/(Imax + Imin) at each spatial frequency (cycle/mm). The results were compared among different situations (fluid-filled or air-filled) for flat or WAV contact lenses.

STUDY RESULTS 1: COMPARISON OF THE FIELD ANGLE OF VIEW

As shown in Table 2, the fundus field angle of view in the air-filled condition was confirmed wider than that in the fluid-filled condition in all tested WAVs by around 10-20° as empirically predicted. Another common thing throughout the currently tested WAVs is that the field

Figure 2. The wide-angle viewing systems evaluated in the current study.

TABLE 1 CONVERTING THE GRATING SCALE OF THE USAF TEST TARGET TO FREQUENCIES (CYCLES/MM)						
USAF grating group	4-1	4-3	5-1	5-3	6-1	6-3
Frequencies (cycles/mm)	16.0	20.2	32.0	40.3	64.0	80.0

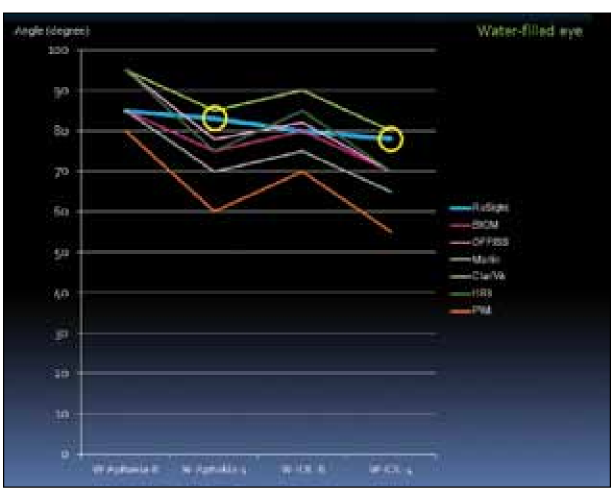

Figure 3. Semiquantitative measurements of the field angle of fundus observed through the wide-angle viewing systems in a model eye filled with water. The yellow circles indicate that the field angle of view of Resight is less influenced by pupil size than any other studied wide-angle viewing systems in the water-filled condition.

angle of view in an aphakic condition is always much wider than that in a pseudophakic or a phakic condition. Among the noncontact type WAVs, the OFFISS gained the widest field angle of view, reaching to 95 degrees in the fluid-filled condition and 125° in the air-filled condition, respectively. The two contact WAV lenses (Clarivit and HRX) also provide similar wide angle of view in both fluid- and air-filled conditions. However, the influences on the field angle of view by the pupil size were quite differences among the WAVs, possibly because of the different in optical designs. Although MERLIN and HRX, both from Volk Optical Inc., have similarly wider field angle of view as compared with other WAVs, the field of view in these recently developed devices is significantly narrowed when viewed through a pupil size of 4 mm diameter in either fluid-filled or air-filled condition (Figure 3). The fundus field viewed through the Resight was most independent of pupil size among the WAVs evaluated in the current study. Through the pupil size of 4 mm, the Clarivit seems to provide the widest field angle for panoramic fundus viewing, followed by the Resight.

STUDY RESULTS 2: COMPARISON OF THE IMAGING CONTRAST VIEWED THROUGH THE WAVS

When viewed through the WAVs, the imaging contrasts at the posterior pole are generally better than those at the periphery, and the contrasts in the fluid-filled condition better than those in the air-filled condition (Figure 4). These findings are consistent with our clinical experiences. When looking at the fundus view at the posterior pole, the grating images observed through the currently studied WAVs were overall well focused. However, again as clinically experienced, the contrasts of the gratings through any WAVs are confirmed slightly lower than those viewed through the flat contact lens at both lower and higher frequencies, even though the differences do not reach significance based on the current semiquantitative measurement techniques (data not shown). As theoretically expected, among the WAVs, the contrasts of the gratings observed through the contact wide-angle viewing lenses were better than those viewed through the noncontact WAVs because the contact lens placed on the cornea can

TABLE 2 COMPARISON OF VISUAL FIELD ANGLE OBSERVED THROUGH VARIABLE WIDE-ANGLE VIEWING SYSTEMS IN AN EYE MODEL						
Status of the vitreous cavity	Lens status	Pupil diameter (mm)	Type of noncontact WAVs	Distance between lens and corneal surface		Contact type (Clarivit/HRX)
				5 mm	3 mm	
Water-filled	Aphakia	8	Resight	85	90	95/90
			BIOM (WiFi 53603)	80	85	
			OFFISS	90	95	
			Merlin	80	85	
			PWL	N/A	80	
		4	Resight	75	80	85/70
			BIOM (WiFi 53603)	60	70	
			OFFISS	65	75	
			Merlin	60	70	
			PWL	N/A	60	
	IOL (20 D)	8	Resight	75	80	85/80
			BIOM (WiFi 53603)	70	75	
			OFFISS	75	80	
			Merlin	70	75	
			PWL	N/A	70	
		4	Resight	70	75	80/65
			BIOM (WiFi 53603)	60	70	
			OFFISS	65	70	
			Merlin	55	65	
			PWL	N/A	55	
Air-filled	Aphakia	8	Resight	115	120	120/115
			BIOM (WiFi 53603)	105	110	
			OFFISS	115	125	
			Merlin	105	110	
			PWL	N/A	100	
		4	Resight	95	110	110/90
			BIOM (WiFi 53603)	80	85	
			OFFISS	85	90	
			Merlin	70	85	
			PWL	N/A	75	
	IOL (20 D)	8	Resight	100	115	115/110
			BIOM (WiFi 53603)	90	105	
			OFFISS	95	110	
			Merlin	90	105	
			PWL	N/A	85	
		4	Resight	95	105	105/85
			BIOM (WiFi 53603)	75	85	
			OFFISS	85	95	
			Merlin	70	80	
			PWL	N/A	70	

BIOM: Binocular indirect ophthalmomicroscope[1]; OFFISS: Optic fiber free intravitreal surgery system[5];
PWL: Peyman-Wessels-Landers semi-wide angle viewing system[7]; Clarivit[9]

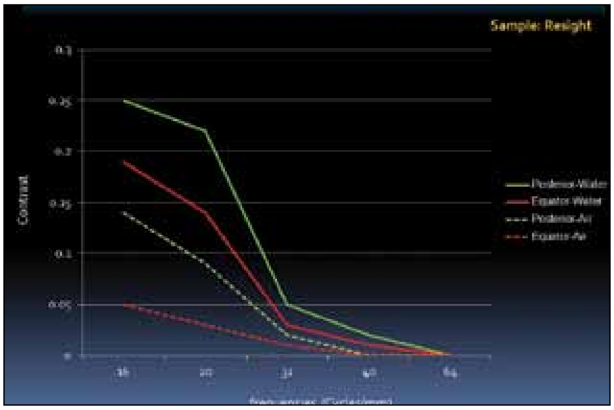

Figure 4. Semiquantitative evaluation of the imaging contrast of fundus viewed through a wide-angle viewing system (Resight) in a model eye.

compensate for corneal aberration and reflection (Figure 5). The differences in the contrasts of the gratings were significantly remarkable at the lower frequencies of 16.0, 20.2, and 32.0 cycles/mm. The contrasts of the gratings at the posterior pole viewed through WAVs, regardless of noncontact type or contact type, are not affected by the pupil size and lens status (aphakia or pseudophakia). Regarding the imaging contrasts at the periphery viewed through the WAVs, semiquantitative measurements of the contrasts of the gratings revealed obvious differences in the imaging quality at the equator among the tested WAVs. We found that the Resight and Clarivit have equally better qualities of contrasts than any other WAVs tested in the current study (Figure 5).

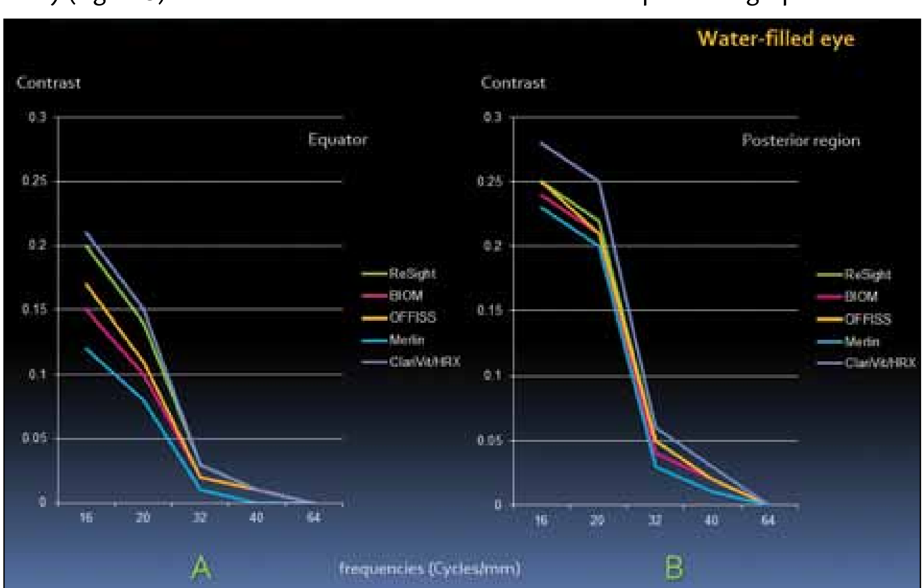

Figure 5. Semiquantitative comparison of the imaging contrast of fundus at the equator (A) and the posterior pole (B) observed through a variety of wide-angle viewing systems.

DISCUSSION

Most WAVs consist of 2 components: an indirect ophthalmoscopic lens system for panoramic fundus observation that is placed on or above the patients' cornea as a contact lens (contact type of WAV) or a preplaced lens (noncontact type of WAV), and a separate removable prismatic stereo reinverter mounted on the surgical microscope for inverting the fundus image. Contact WAVs have a fixed field angle of view depending on the magnification power of the lens, whereas the field angle of view in noncontact systems can be adjusted by changing the distance between the preplaced lens and the corneal surface. Although both types of WAVs can gain magnified fundus images by zooming of the surgical microscope, the image resolution (imaging clarity) is theoretically superior with the contact type system because the aberration and reflection from the corneal surface can be compensated by directly placing the lens on the corneal surface. On the other hand, because the contact lens placed on the cornea often needs an experienced assistant to hold the lens during surgery, and because of the complexity in the inverted footswitch control for the X-Y imaging movement, most surgeons have preferred to use noncontact wide-angle viewing systems (PAT survey 2005).

Based on the current semiquantitative assessments in an eye model, we confirmed that wider fundus view can be obtained through aphakic status than through phakic or pseudophakic status. Similarly, wider panoramic fundus view can be obtained in an air-filled condition than in a fluid-filled condition. Based on these findings, when performing a phaco-vitrectomy, it might be better for the surgeon to complete the overall intravitreal manipulations with or without fluid-air exchange followed by IOL implantation to obtain wider fundus panoramic viewing and easy access to the peripheral regions during vitreous surgery. Next, according to the results of field angle measurement through a pupil diameter of 4 mm, to perform vitrectomy in patients with poorly-dilated pupils, we found the Resight or Clarivit may be a better choice than other WAVs because the field angle of view through the Resight or Clarivit was less affected by pupil size. Among the

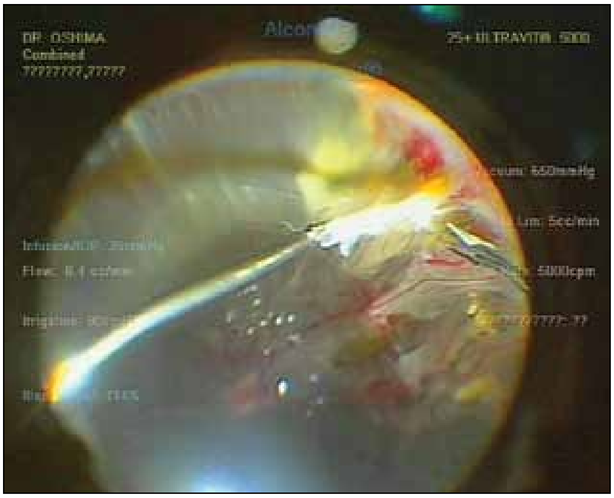

Figure 6. Bimanual membrane dissection observed through the Resight. A clear and wide-field view of the fundus from the posterior through the periphery was obtained.

various WAVs evaluated in the current study, the widest panoramic view was obtained when viewing through the OFFISS at a pupil diameter of 8 mm. However, the imaging quality (contrast) at the equator observed through the OFFISS did not exceed that observed through either the Resight or Clarivit. Imaging contrast is another critical factor for viewing and manipulation during vitrectomy. The current results of contrast evaluation are consistent with our clinical experiences: that the Resight and Clarivit likely have lower imaging distortion than other WAVs through which we see the periphery. When viewing the posterior pole, the Clarivit, a contact type WAV lens, having the best imaging quality, is also compatible with the optic theory as described above. In contrast, the Resight, the latest noncontact type WAV, has a similar quality of imaging contrast at the posterior pole as compared with Clarivit at any measured frequencies.

The WAVs introduced in recent years have further facilitated the widespread use of microincisional approaches for pars plana vitrectomy. Using WAVs, the full extent of the vitreous base, where residual traction often causes surgical failure, can be exposed and accessible for surgical manipulation, even using small gauge instruments without the need for scleral indentation (Figure 6). Based on the current study results of semiquantitative measurements in vitro, the Resight and Clarivit seem to be the most well-balanced WAVs for vitreous surgery because of their wider angle field of view almost independent of pupil size and the high quality of imaging contrast at both the posterior pole and periphery. Considering the necessity of bimanual surgery for dissecting proliferative membranes from the posterior pole to the periphery in complicated cases, however, contact WAVs may prove difficult for the surgeon to control and often require an assistant to hold the lens during surgery. In my opinion, the Resight is a better choice, being a noncontact WAV and thus the most convenient and easy-to-use system for treating challenging MIVS cases. The newest WAVs should enhance the surgeons' manipulative abilities by providing not only a wide field view of the fundus, but also high-resolution fundus images, contributing to safety and easing the technical difficulties of vitreous surgery. ■

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