Int J Ophthalmol, Vol. 11, No. 11, Nov.18, 2018 www.ijo.cn
Tel:8629-82245172 8629-82210956 Email:ijopress@163.com

· Clinical Research ·

Preventing condensation of objective lens in noncontact wide-angle viewing systems during vitrectomy

Jung Pil Lee[1], *Jinsoo Kim*[2], *Inwon Park*[2], *Ho Ra*[3], *Soonil Kwon*[2]

[1]Department of Ophthalmology, Incheon Medical Center, Incheon 22532, Republic of Korea
[2]Department of Ophthalmology, Hallym University Sacred Heart Hospital, Anyang 14068, Republic of Korea
[3]Department of Ophthalmology, Bucheon St.Mary's Hospital, Bucheon, College of Medicine, the Catholic University of Korea, Seoul 14647, Republic of Korea

Correspondence to: Soonil Kwon. Department of Ophthalmology, Hallym University Sacred Heart Hospital, 22, Gwanpyeong-ro 170beon-gil, Dongan-gu, Anyang 14068, Gyeonggi Province, Republic of Korea. magicham@hallym.or.kr; Ho Ra. Department of Ophthalmology, Bucheon St.Mary's Hospital, 327, Sosa-ro, Bucheon 14647, Republic of Korea. raho@catholic.ac.kr

Received: 2018-02-27 Accepted: 2018-06-07

Abstract

● AIM: To assess the optimal conditions for preventing condensation of objective lens during vitrectomy with noncontact wide-angle viewing systems (WAVSs).

● METHODS: We explored the effectiveness of the coating with ophthalmic viscoelastic device (OVDs) on the corneal surface and the soaking the objective lens in warm-saline for preventing condensation of objective lens. First, to find the optimal soaking time to keep the objective lens warm, we measured the temperature of objective lens every minute after soaking in warm saline. Second, to find optimal distance between cornea and objective lens, which provide as wide a view as possible and less condensation at the same time, we measured the condensation time with different distances. With the obtained optimal soaking time and distance, we explored the effect of coating cornea with OVDs and soaking objective lens in warm saline on condensation time.

● RESULTS: One and 5min of soaking in warm saline was most effective for keeping the lens warm enough (45.1℃±2.1℃ for 1min and 46.4℃±1.0℃ for 5min, *P*=0.109). The mean condensation times for the control group at 1, 3, and 5 mm from corneal surface to objective lens were 1±0.4, 4±1.4, 190±26.1s, respectively, thus 5 mm was most optimal distance for vitrectomy with WAVSs. For the OVD coating group, the mean condensation times were 1.5±0.3, 13±1.4, and 200±23.9s at 1, 3, and 5 mm distance and borderline significant compared with control group (*P*=0.068, 0.051, and 0.063, respectively). With the 1-minute warm saline soaking group, the mean condensation time were extended to 188±34.4, 416±65.7, and 600±121.3s at 1, 3, and 5 mm distance and statistically significant compared with control (*P*=0.043, 0.041 and 0.043, respectively).

● CONCLUSION: OVD coating on corneal surface shows no difference on condensation time with control group. However, soaking the objective lens in warm saline revealed statistically significant extension of condensation time compared to control group. Therefore, keeping the objective lens warm with soaking in warm saline is a simple but effective to prevent condensation of objective lens during vitrectomy. The thermodynamics between objective lens and cornea during vitrectomy warrants further investigation.

● KEYWORDS: condensation; vitrectomy; warm saline; wide-angle viewing systems

DOI:10.18240/ijo.2018.11.12

Citation: Lee JP, Kim J, Park I, Ra H, Kwon S. Preventing condensation of objective lens in noncontact wide-angle viewing systems during vitrectomy. *Int J Ophthalmol* 2018;11(11):1809-1813

INTRODUCTION

Obtaining good visualization is a fundamental step in performing safe and effective surgery. Wide-angle viewing systems (WAVSs) are useful observation devices for vitreoretinal surgery. WAVSs not only offer a wide surgical field of view but also improve the safety and efficiency of surgical procedures[1-2]. There are two types of WAVs: the contact lens system and the noncontact lens system. Each of the systems has advantages and disadvantages[3-12].

The field of view in noncontact WAVSs depends primarily on the distance between the objective lens surface of the operating microscope and the corneal surface[13]. As the objective lens approaches the cornea, the observed field grows larger and wider, but water tends to condense easier. On the contrary, as the lens drifts away from the cornea, the observation field becomes smaller and narrower, but it takes more time for condensation to occur. Therefore, surgeons should maintain an optimal distance between the objective lens and the cornea in order to obtain as wide a view as possible but not have that field be frequently obscured by condensation. However, surgeons sometimes have to view the far periphery for shaving peripheral vitrectomy procedure or localizing lesions, and it is disruptive to have to stop to wipe out condensation droplets.

Condensation develops when vapor contacts low-temperature surfaces[14]. Therefore, surgeons can prevent condensation by lowering vapor pressure or raising the lens surface temperature. In practice, we have empirically used several methods to prevent condensation. One of them is coating the cornea with ophthalmic viscoelastic devices (OVD). This seems effective for lowering the vapor pressure by preventing frequent corneal irrigation. Another method is to use warm saline to raise the temperature of the objective lens surface. Unfortunately, there is no data or study about the effectiveness of those methods on preventing condensation during vitrectomy. In this study, we investigated the efficiency of coating the cornea with OVDs and soaking the objective lens in warm saline in order to prevent condensation during vitrectomy with noncontact WAVSs.

SUBJECTS AND METHODS

This experimental study was conducted in accordance with the tenets of the Declaration of Helsinki and was approved by the Institutional Review Board of Hallym University Sacred Heart Hospital. The written informed consents of all the participants to experiment and the research agreements were obtained. All three of the authors (Lee JP, Kim J and Kwon S) volunteered to provide the human corneal environment for the experiments. Neither of the authors has systemic medical or ophthalmic histories. Experiments were performed in an operating room with a noncontact WAVS (Resight, Carl Zeiss Meditec AG, Germany) and with human eyes in order to provide a simulated operating environment. The objective lens used in the experiments is the one used in vitrectomy, therefore the lens was rinsed and maintained by the standard protocol for surgical instrument.

The area of the room was 30.6 square meters. Three people participated in the room and the door remained closed during the experiments. The environmental temperature and humidity were relatively constant because the operating room is controlled 24h. The operating room was ensured to maintain the temperature between 18℃ and 24℃ and the relative humidity between 40% to 60%. Room temperatures and relative humidity were recorded immediately prior to any experiments (20.2℃±1.7℃ and 50.7%±3.5%). The investigation comprised four separate experiments, as follows.

Experiment 1, to find the optimal soaking time of the objective lens. The purpose of the first experiment was to determine the optimal soaking time that could keep the lens warm as long as possible. After soaking the lens in warm saline for 1, 5, 10, 15 and 20min, we measured the surface temperature every minute until the lens cooled down to room temperature. We used the warm saline that is always prepared in the heating cabinet.

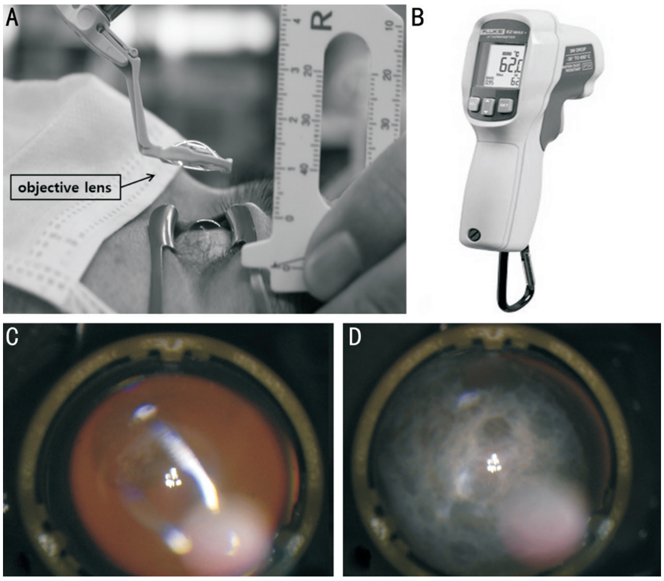

Figure 1 Overview and instruments of the experiments A: Measuring distance from the corneal surface to the objective lens; B: Fluke 62 MAX noncontact infrared thermometer (Fluke Corp, Washington, USA); C: Objective lens before condensation; D: Objective lens with condensation.

Experiment 2, condensation time corresponding to the distance between the cornea and the objective lens with no treatment. We explored the condensation time corresponding to the distance between the cornea and the objective lens. The distance between the cornea and objective lens was adjusted using a ruler (Figure 1A). We measured the time to condensation development in any part of the lens, adjusting the distance to 1, 3, 5, and 7 mm from the corneal surface (Figure 1C, 1D). The subject's cornea was exposed *via* speculum during the experiments and irrigated every 30s with balanced salt solution (BSS) in order to avoid desiccation. All three authors provided corneal environments for three experiments each.

Experiment 3, condensation time corresponding to the distance between the cornea coated with viscoelastics and the objective lens. After coating the cornea surface with the dispersive OVDs (Viscoat, Alcon Corp., Japan), we measured the condensation time in the same manner as in Experiment 2. BSS irrigation was not required for this experiment.

Experiment 4, condensation time corresponding to the distance between the cornea and the objective lens soaked in warm saline. After finding the optimal soaking time from Experiment 1, we repeated Experiment 2 after soaking the objective lens in warm saline for the optimal time period. Every experiment was repeated total 4 times in one session to obtain enough data for a parametric statistical test. A total of 3 sessions were performed on different days. A Fluke 62 MAX noncontact infrared thermometer (Fluke Corp, Washington, USA) was

Table 1 Changes of temperature of objective lens over time according to various soaking time ℃

Soaking time	Elapsed time (min)											
	1	2	3	4	5	6	7	8	9	10	15	20
1min	45.1±2.1	38.1±1.6	32.1±2.5	27.4±1.0	25.0±2.3	22.5±1.8	22.2±1.5	20.1±1.9	20.0±1.9	19.8±1.7	19.5±1.5	18.3±0.9
5min	46.4±1.0 (0.109)	38.7±0.6 (0.498)	33.4±1.4 (0.131)	28.4±1.5 (0.059)	26.6±0.9 (0.074)	23.3±1.6^a (0.038)	23.2±1.5^a (0.025)	22.0±1.9^a (0.034)	21.4±1.6^a (0.038)	20.6±1.0 (0.102)	19.6±1.0 (0.892)	18.5±1.1 (0.581)
10min	36.4±1.7^a (0.043)	33.2±1.3^a (0.043)	27.9±2.2^a (0.041)	25.9±1.4^a (0.041)	23.2±1.2 (0.066)	21.1±1.2 (0.068)	21.8±1.6 (0.317)	20.3±1.5 (0.564)	19.9±1.4 (0.785)	19.5±1.5 (0.461)	18.5±0.4 (0.334)	18.1±0.7 (0.713)
15min	36.1±2.2^a (0.043)	31.9±1.9^a (0.042)	27.6±1.6^a (0.042)	25.6±1.7^a (0.041)	23.8±2.1 (0.083)	21.5±1.2 (0.279)	21.6±1.0 (0.450)	19.8±1.2 (0.683)	19.5±1.1 (0.257)	19.4±1.0 (0.317)	19.5±1.2 (0.891)	18.4±0.8 (0.705)
20min	35.8±1.6^a (0.043)	31.8±0.9^a (0.042)	27.4±1.4^a (0.042)	25.5±1.6^a (0.042)	24.4±2.4 (0.334)	23.0±2.3 (0.285)	23.3±1.9 (0.109)	21.6±1.2 (0.276)	21.1±1.0 (0.498)	20.9±0.7 (0.498)	19.7±1.3 (0.893)	19.1±1.2 (0.273)

Values are presented as the mean±standard deviation (*P* value). The *P* values are generated by comparing 1-minute time group with other experimental groups (5, 10, 15 and 20min groups). $^a P<0.05$ Student's *t*-test.

used for corneal and lens temperature measurements (Figure 1B). The Fluke 62 MAX noncontact infrared thermometer can evaluate temperatures between -30℃ and 500℃ with a resolution of 0.1℃ and ±1.5% accuracy (information provided by the manufacturer).

Statistical Analysis Statistical analysis was performed using SPSS software, version 18.0 (SPSS, Inc., Chicago, IL, USA). The Student's *t*-test was used to compare the mean change in temperature at each time point and the condensation time at each distance between study groups. The level of significance was set at 0.05.

RESULTS

Change of Objective Lens Temperature Table 1 and Figure 2 show the serial changes in mean objective lens temperature after warm saline soaking. The baseline temperatures of warm saline and the corneal surface were 63℃±4.3℃ and 29.1℃±0.5℃, respectively. The highest temperature of objective lens was measured at 5-minute soaking in warm saline (46.4℃±1.0℃) but there was no significant difference in with the temperature after 1- minute soaking (45.1℃±2.1℃, *P*=0.109). On the other hand, the lenses soaked for 10, 15, and 20min showed significantly lower temperatures compared with the lenses soaked for 1min or 5min in saline. In other words, the lenses soaked in warm saline for 1 to 5min could maintain high temperature longer than the lenses soaked for more than 10min. The temperature of the lenses soaked in warm saline for 1 and 5min cooled down to corneal temperature, the point at which condensation could occur, in 3min 40s and 4min 50s, respectively, while the temperatures of the 10-, 15-, and 20-minute groups decreased to corneal temperature in less than 3min (Figure 2).

Condensation Time Experiment 1 showed that the lens soaked in warm saline for 1 to 5min maintained higher temperatures than the corneal surface for about 4 to 5min (Figure 2). Because there was no statistical difference between 1 and 5min, we used 1min as the optimal soaking time in Experiment 4.

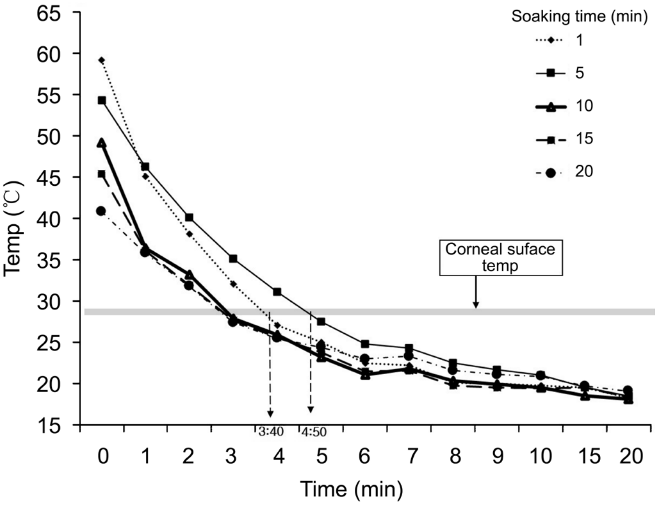

Figure 2 Changes of the objective lens temperature according to various soaking time The temperature of lens soaked in warm saline for 1min and 5min cooled down to corneal temperature (grey band) in 3min 40s and 4min 50s, respectively *P*>0.05.

From Experiments 2, 3, and 4, we were able to obtain the condensation times for various distance settings in each group. The mean condensation times for the control group at 1, 3, and 5 mm from corneal surface to objective lens were 1±0.4, 4±1.4, 190±26.1s, respectively. Mean condensation times for the OVD coating group were 1.5±0.3, 13±1.4, and 200±23.9s at 1, 3, and 5 mm, respectively for the OVD coating group. Mean condensation times for the 1-minute warm saline soak group were 188±34.4, 416±65.7, and 600±121.3s at 1, 3, and 5 mm, respectively (Table 2, Figure 3). There were trend of increasing condensation time in OVD coating group, compared to control group, but no statistical differences were found in the condensation time between control and OVD coating groups at any distance (*P*=0.068, 0.051, and 0.063, respectively). In warm saline soaking group, the condensation time was higher than that of the control at 1, 3, and 5 mm distances (*P*=0.043, 0.041 and 0.043, respectively). The condensation time at 7 mm distance was over 1000s in all groups (Figure 3).

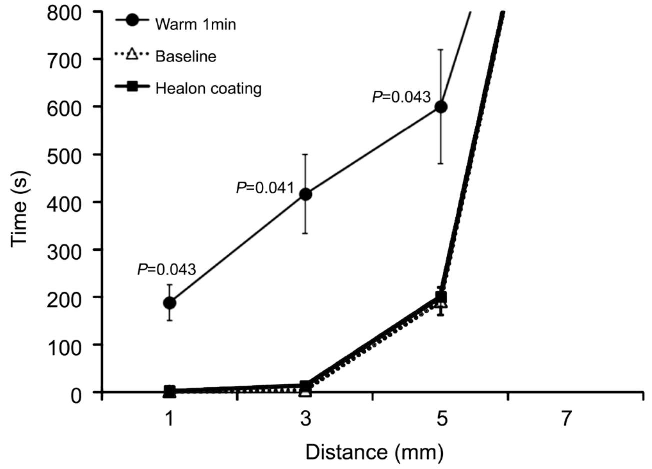

Figure 3 Condensation time of the control, OVDs coating group and warm saline soaking group Student's *t*-test, $P<0.05$.

Table 2 Condensation time for each different group by distance between corneal surface and objective lens

Distance (mm)	Time (s)		
	Control	OVDs coating	Saline soaking
1	1±0.4	1.5±0.3 (0.068)	188±34.4 (0.043[a])
3	4±1.4	13±1.4 (0.051)	416±65.7 (0.041[a])
5	190±26.1	200±23.9 (0.063)	600±121.3 (0.043[a])
7	>1000	>1000	>1000

Values are presented as the mean±standard deviation (*P* value); The *P* values are generated by comparing control group and other experimental groups (OVD coating and saline soaking); Student's *t*-test, [a]$P<0.05$.

DISCUSSION

A noncontact WAVS for vitreoretinal surgery has many advantages over a contact WAVS, including not requiring an assistant and easily maintaining a good image during eye movement. Contact WAVSs have a fixed field angle of view, whereas the field angle of view in noncontact WAVSs can be adjusted by changing the distance between the objective lens and the corneal surface[13]. Therefore, many surgeons have preferred to use noncontact WAVSs. However, intraoperative condensation on the objective lens can occur, especially during peripheral shaving procedures when the objective lens gets closed to corneal surface (Figure 1C, 1D). Condensation can severely interfere with the surgeon's view and prolong the operation time. Because condensation occurs when warm water vapor contacts a cool surface, condensation occurs much more easily when the lens is in close proximity to the warm and wet corneal surface. The current study compared the distance between an objective lens and the corneal surface to investigate the optimal distance for obtaining a sufficiently wide surgical view while also preventing condensation. In fact, 3 mm is the minimal distance that can be set for clinical use, but condensation occurs too quickly. However, when the distance is set to 5 mm, it generally takes 2 or 3min for condensation to begin (190±26.1s; Table 2). Although the visual field angle is narrower than that of the 3 mm distance setting by just 5 degrees, it is wide enough for peripheral area operations[15]. Therefore, we believe 5 mm is the optimal distance for peripheral surgery. However, 2 to 3min is too short for some procedures, and the time to condensation becomes even shorter when the lens is set closer for peripheral visualization. Therefore adjuvant method to extend condensation time is necessary for these situations.

Condensation can be prevented by either lowering the vapor pressure (relative humidity) or increasing the lens temperature[14]. Recently, Kusaka *et al*[16] reported antifogging device to reduce vapor pressure between objective lens and cornea during vitrectomy with wide-angle viewing system. In practice, there are some widely known methods for preventing condensation, though these have not been definitively investigated. Use of OVDs is a commonly used method because the corneal wetting properties may prevent the need for frequent irrigation of the corneal surface. Repeated irrigation with BSS to maintain a clear surgical view increases the vapor pressure around the lens surface, leading to condensation. Theoretically, OVDs should be effective in preventing condensation. The current study, which investigated how effectively OVDs can prevent condensation, discovered that the condensation time with the OVD group was slightly increased from the control group with borderline statistical significance (*P*=0.068, 0.051, and 0.063; Table 2).

Another means to delay condensation is to increase the temperature of the objective lens. Soaking lens in warm saline is simple way to increase the temperature of an objective lens. It has been generally believed that the longer a lens soaks in saline, the longer it may maintain the temperature of the lens. However, in Experiment 1, we found that the outcome was not significantly different whether the lens was soaked for just 1min or for 5min. On the contrary, if the lens was soaked for more than 5min, the surface temperature of the lens became lower than that of the 1-minute soaking group due to cooling of the saline solution itself. Our experiments allow us to safely conclude that a lens does not have to be soaked in saline for longer than five minutes in order to obtain warm enough objective lens. As shown in Figure 2, if the lens is soaked in warm saline for one to five minutes, the temperature of the lens will be maintained higher than that of the cornea for approximately 4 to 5min. In other words, soaking the objective lens for 1 to 5min can extend the time to condensation to 4 to 5min. Extension of the condensation time, from 1 to 190s in control group to 188 to 600s in the 1-minute saline soaking group (Table 2), supports this assumption.

Although the study has yielded some preliminary findings, there are some limitations in this study. The first limitation is the small number of subjects. Only 3 test subjects participated in this experiment and to overcome the small number of subjects, all the experiments were repeated several times. In a real operation, ocular temperature changes according to the steps of operation process, which was not reflected in this study. However, the ocular temperature generally decreases during vitrectomy[17-20]. Lower temperature during vitrectomy will further delay condensation time than experiment in our study, so this would not significantly affect our results. Third, even though saline soaking could extend condensation time a little, the distance between objective lens and cornea usually got very close during peripheral shaving procedure, and would be easily obscured. Therefore the "warm saline soaking" method could not very practical in real world.

Even with the aforementioned limitations, this is the first experimental study to find out the effective methods for preventing condensation during vitrectomy. Moreover, our study provided objective data about the empirical methods which retinal surgeons have applied in the field. We believe our work generates important findings, including the optimal distance between the lens and the corneal surface in noncontact WAVSs to obtain the widest possible surgical view while preventing condensation as much as possible. In addition, we could confirm that elevating surface temperature of objective lens could prevent condensation and provide clear operation field during surgery. If we can find the way to maintain objective lens warmer than cornea during surgery, such as something like a defroster in a car window, it could save much time and lead to efficient operation.

In conclusion, while OVD coating on corneal surface showed no difference on condensation time with control group, soaking the objective lens in warm saline showed statistically significant extension of condensation time compared to control group. Soaking the objective lens in warm saline can extend the condensation time and might be helpful for obtaining a clear surgical view. It will be necessary to find the way to keep the objective lens warm long and steady for efficient operation in future study.

ACKNOWLEDGEMENTS

Authors' contributions: Kwon S contributed to study design, data collection, analysis, and interpretation, and was primarily responsible for writing the manuscript. Lee JP, Park I and Kim J contributed to data collection and interpretation, and revised the manuscript. Ra H contributed to analysis, and interpretation and provided significant information for manuscript writing. All authors read and approved the final manuscript.

Conflicts of Interest: Lee JP, None; **Kim J,** None; **Park I,** None; **Ra H,** None; **Kwon S,** None.

REFERENCES

1 Chalam KV, Shah VA. Optics of wide-angle panoramic viewing system-assisted vitreous surgery. *Surv Ophthalmol* 2004;49(4):437-445.

2 de Oliveira PR, Berger AR, Chow DR. Vitreoretinal instruments: vitrectomy cutters, endoillumination and wide-angle viewing systems. *Int J Retina Vitreous* 2016;2:28.

3 Nakata K, Ohji M, Ikuno Y, Kusaka S, Gomi F, Kamei M, Ross DF 3rd, Tano Y. Wide-angle viewing lens for vitrectomy. *Am J Ophthalmol* 2004;137(4):760-762.

4 Bovey EH, Gonvers M. A new device for noncontact wide-angle viewing of the fundus during vitrectomy. *Arch Ophthalmol* 1995;113(12):1572-1573.

5 Spitznas M. A binocular indirect ophthalmomicroscope (BIOM) for non-contact wide-angle vitreous surgery. *Graefes Arch Clin Exp Ophthalmol* 1987;225(1):13-15.

6 Horiguchi M, Kojima Y, Shimada Y. New system for fiberoptic-free bimanual vitreous surgery. *Arch Ophthalmol* 2002;120(4):491-494.

7 Landers MB, Peyman GA, Wessels IF, Whalen P, Morales V. A new, non-contact wide field viewing system for vitreous surgery. *Am J Ophthalmol* 2003;136(1):199-201.

8 Chihara T, Kita M. New type of antidrying lens for vitreous surgery with a noncontact wide-angle viewing system. *Clin Ophthalmol* 2013;7:353-355.

9 Ohji M, Tada E, Futamura H. Combining a contact lens and wide-angle viewing system for a wider fundus view. *Retina* 2011;31(9):1958-1960.

10 Ohno H. Combined use of high-reflective index vitrectomy meniscus contact lens and a noncontact wide-angle viewing system in vitreous surgery. *Clin Ophthalmol* 2011;5:1109-1111.

11 Kita M, Fujii Y, Kawagoe N, Hama S. Scleral buckling with a noncontact wide-angle viewing system in the management of retinal detachment with undetected retinal break: a case report. *Clin Ophthalmol* 2013;7:587-589.

12 Park SW, Kwon HJ, Kim HY, Byon IS, Lee JE, Oum BS. Comparison of scleral buckling and vitrectomy using wide angle viewing system for rhegmatogenous retinal detachment in patients older than 35y. *BMC Ophthalmol* 2015;15:121.

13 Inoue M. Wide-angle viewing system. *Dev Ophthalmol* 2014;54:87-91.

14 Porter RG, Peters JD, Bourke RD. De-misting condensation on intraocular lenses. *Ophthalmology* 2000;107(4):778-782.

15 Oshima Y. Choices of wide-angle viewing systems for modern vitreoretinal surgery. *Retina Today* 2012;7(6):37-42.

16 Kusaka S, Tachibana K, Tsujioka D, Hotta F, Eguchi H, Shimomura Y. Antifogging device to prevent moisture condensation during vitrectomy with noncontact wide-field system. *Retina* 2017;37(6):1215-1217.

17 Landers MB 3rd, Watson JS, Ulrich JN, Quiroz-Mercado H. Determination of retinal and vitreous temperature in vitrectomy. *Retina* 2012;32(1):172-176.

18 Romano MR, Vallejo-Garcia JL, Romano V, Angi M, Vinciguerra P, Costagliola C. Thermodynamics of vitreoretinal surgery. *Curr Eye Res* 2013;38(3):371-374.

19 Tamai K, Toumoto E, Majima A. Protective effects of local hypothermia in vitrectomy under fluctuating intraocular pressure. *Exp Eye Res* 1997;65(6):733-738.

20 Horiguchi M, Miyake Y. Effect of temperature on electroretinography readings during closed vitrectomy in humans. *Arch Ophthalmol* 1991;109(8):1127-1129.