ARTICLE

Macular photostress and visual experience between microscope and intracameral illumination during cataract surgery

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Purpose: To evaluate macular photostress and visual experience between coaxial microscope illumination versus oblique intracameral illumination during cataract surgery.

Setting: Gachon University Gil Hospital, Incheon, South Korea.

Design: Prospective case series.

Methods: Consecutive patients who had cataract surgery using microscope illumination and intracameral illumination were included. The patients were asked to complete a questionnaire (seeing strong lights, feeling photophobia, feeling startled (fright) when seeing lights, seeing any colors, seeing any instruments or surgical procedures, and estimating intraoperative visual function) designed to describe their cataract surgery experience. The images projected on the retina of the model eye (rear view) with artificial opaque fragments in the anterior chamber during simulating cataract surgery were compared between the 2 illumination types.

Results: Sixty patients completed the questionnaire. Scores for strong lights, photophobia, fright, and color perception were significantly higher with microscope illumination than with intracameral illumination (all $P < .001$). More patients preferred the intracameral illumination (45 [75.0%]) to the microscope illumination (13 [21.7%]). In the rear-view images created in a model eye, only the bright microscope light in the center was seen without any lens image in the microscope illumination. However, in the intracameral illumination, the less bright light from the light pipe in the periphery and the lens fragments were seen more clearly.

Conclusions: In a view of the patients' visual experience, oblique intracameral illumination caused less subjective photostress and was preferred over coaxial microscope illumination. Objective findings from the model-eye experiment correlated to the result of visual experience.

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Cataract surgery is 1 of the most common operations performed today. Phacoemulsification cataract surgery is not possible without an ophthalmic operating microscope. A red reflex, produced by reflection of coaxial light from the macula back to the observer, provides the ideal contrast necessary for visualization during cataract surgery. A good red reflex is 1 of the most important features of an ophthalmic microscope for cataract surgery.

However, if the eye moves or the position of the microscope changes, then the red reflex is lost, making critical stages of the cataract procedure, such as phacoemulsification, difficult and even dangerous. In some cases, this loss can make the case more difficult, especially in eyes with corneal opacity, a small pupil, or advanced cataract.[1] Visualization can be challenging because of the view or because of the pathology.

A new illumination system with intracameral illumination might overcome these drawbacks. An advanced cataract surgery technique using oblique intracameral illumination has been introduced with real-time high-quality lens images.[1–4] The intracameral illumination might contribute significantly to optimal visualization in standard cataract surgery.

Ophthalmic operating microscopes must provide not only good visibility for the surgeon but also comfort and minimization of macular photostress for the patient. One source of discomfort and macular photostress for patients

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is a bright coaxial light shining into the macula, which is associated with traditional microscopes.[5] Increasing clinical experience with intracameral illumination has provided us with a better understanding of certain features of this new technology. We believe that an oblique illumination with this intracameral technique rather than a bright coaxial light from a traditional microscope makes surgery more tolerable for the patient and the surgeon. More importantly, with concern about coaxial light from the microscope reaching macular phototoxic levels, this alternative illumination technique using oblique light focused onto the lens offers the advantage of reduced direct illumination of the macula.[1–4,6]

To confirm this clinical observation, we performed a prospective intraindividual comparative questionnaire survey and a laboratory evaluation in a model eye simulating cataract surgery to assess subjective and objective macular photostress between microscope versus intracameral illumination during phacoemulsification cataract surgery.

PATIENTS AND METHODS

Patients

Gachon University Institutional Review Board (GAIRB2016-065) approved this study before its initiation. The patients participated with full informed consent and the study adhered to the tenets of the Declaration of Helsinki. To prospectively and objectively study the clinical impression that intracameral illumination is well tolerated by patients during the procedure and that subjective macular photostress is less than microscope illumination, patients were asked to complete a questionnaire designed to describe their cataract surgery experience in the immediate postoperative period. This took place from September 2015 to March 2016 at the Department of Ophthalmology, Gachon University Gil Hospital, Incheon, South Korea.

Inclusion criteria included patient age older than 40 years and senile cataracts as a surgical indication. Exclusion criteria consisted of patients with deafness; dementia; high anxiety; involuntary movement disorders; complicated cataracts, such as a small pupil, mature lens, previous trauma, or zonular fiber weakness; previous intraocular surgery; or surgical time longer than 25 minutes. Aiming to detect a difference of 1 in a 10-point visual analogue scale (VAS) with a power of 80%, assuming a standard deviation of 2.75, a sample size of 60 patients for statistical evaluation was calculated.

Surgical Procedure

The surgical technique described in our previous studies[1–4] was used in all cataract surgeries, including advanced lens capsule polishing. An operating microscope with coaxial illumination (M844 C40, Leica Microsystems GmbH) was used for all operations with the light intensity set at 70%. To optimize visualization at all stages of the cataract surgery, illumination was changed and customized according to the varying requirements of different surgical procedures and eyes. The procedure switched back and forth between the microscope illumination (type 1) and the intracameral illumination (type 2) (Xenon Brightstar, D.O.R.C. International BV) depending on which phase of surgery was being performed and to avoid blending the 2 illumination systems (Figure 1). Sub-Tenon anesthesia was administered using 0.5 mL to approximately 1.0 mL of lidocaine 2.0%. Neither oral nor intravenous sedatives and/or analgesics that would impair a patient's cognitive function were administered. Frequent dialogue was maintained with the patients during the procedure. All procedures were performed by 2 physicians (D.H.N., J.Y.L.).

Postoperative Evaluation

The patients were informed of the interview preoperatively and asked to concentrate on what they would see during surgery. The questionnaire (seeing strong lights, feeling photophobia, feeling startled [fright] when seeing lights, seeing any colors, seeing any instruments or surgical procedures, and estimating intraoperative visual function) was administered immediately after surgery in the postoperative recovery room. The questionnaire used a VAS format in which patients were asked to rate the variables on a scale of 0 to 10, with 10 being the most severe. They were also asked a closed-ended question: Which do you prefer, microscope illumination or intracameral illumination? The scores of 2 illumination types in each question were compared. In addition, further analyses were performed to determine clinical factors associated with the degree of perception in each illumination. A subgroup analysis was also performed according to the preferred illumination type for the type 1 group and type 2 group.

A review of medical records was performed in which demographic data, medical history, ocular history, corrected distance visual acuity, slitlamp evaluation including lens scoring (Lens Opacities Classification System III[7]), dilated fundus examination, and fundus photography were collected and reviewed.

Model Eye

A model eye constructed to mimic the ideal human eye was used to simulate the visual experience of the patients as described by Inoue et al.[8] The cornea and the posterior surface of the model eye were made of transparent poly(methyl methacrylate). The inner surface of the posterior surface was uniformly frosted so that images on the surface could be seen from the back. An artificial opaque fragment to mimic a cataract lens was inserted into the anterior chamber of a model eye and the model eye was filled with a balanced salt solution at room temperature. The eye was fixated so that the light from a surgical microscope entered the pupil along the optical axis of the model eye or a 25-gauge light pipe was inserted to illuminate intracamerally (Figure 2). The images projected on the frosted surface were recorded by the digital camera (EOS KISS X3, Canon, Inc.) and the images of the objects in the anterior chamber as seen through the surgical microscope were simultaneously recorded. The position of the digital camera was inverted because the images projected on the human retina are inverted images and the images are reinverted in the brain.

Statistical Analyses

All statistical analyses were performed using SPSS software (version 12.0, SPSS, Inc.). The paired t test and chi-squared test were conducted for univariate analysis to show the significance of differences between microscope illumination and intracameral illumination. Simple linear regression, stepwise multiple linear regression, and logistic regression tests were used to determine significant clinical factors associated with the result of each question. A P value of 0.05 or less was considered statistically significant.

RESULTS

Patients

Sixty-two consecutive patients participated in the study preoperatively and 60 patients completed the questionnaire. Two patients did not answer because of severe fatigue or could not recall the events during their surgery. No patient experienced intraoperative complications such as posterior capsule rupture or zonular dialysis. Table 1 shows the patient demographics.

Table 2 shows the scores for each question according to the type of illumination. The scores for strong lights (question 1), photophobia (question 2), fright (question 3), and color perception (question 4) were significantly higher

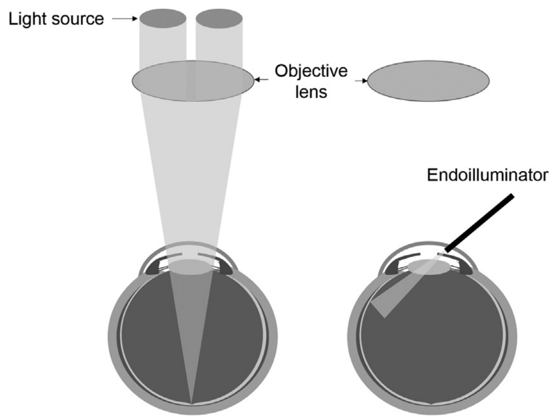

Figure 1. Microscope illumination (type 1) (*left*) versus intracameral illumination (type 2) (*right*). With type 1 illumination, 1 source of discomfort and macular photostress is a bright coaxial light shining into the macula, which might induce macular phototoxicity. With type 2 illumination, although it is a side light of intracameral illumination rather than a bright front light of the microscope, it might make surgery more tolerable for both the patient and the surgeon, and provide reduced direct illumination of the macula.

with type 1 illumination than with type 2 illumination (all $P < .001$). The average score for seeing instruments or surgical procedures (question 5) was higher in type 2 illumination with borderline significance, whereas that of estimating intraoperative visual function (question 6) was higher in type 1 illumination with borderline significance ($P = .085$ and $P = .078$, respectively). In the closed-ended question about illumination preference (question 7), 13 patients (21.7%) preferred type 1 illumination and 45 patients (75.0%) preferred type 2. Two patients (3.3%) did not express a preference.

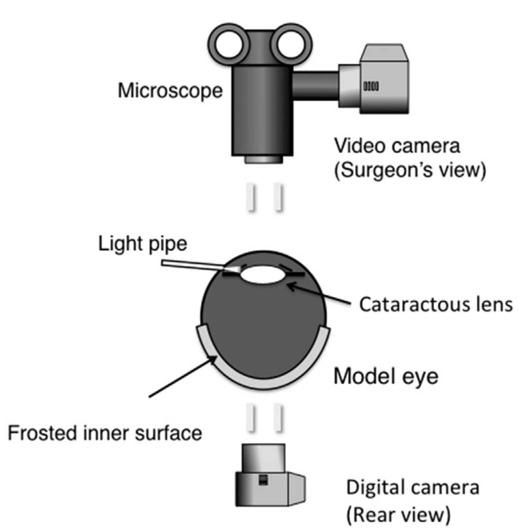

Figure 2. Schematic diagram of the experimental setup of the model eye. The images projected on the frosted posterior surface of the model eye (*rear view*) are recorded from the rear by a commercial digital camera. The images seen through the surgical microscope (*surgeon's view*) are also recorded by the video camera attached to the microscope.

Further analyses were performed to determine clinical factors associated with the degree of perception in each illumination. Age, sex, presence of coexisting ocular pathology, presence of cortical opacity, anterior cortical opacity, and posterior subcapsular opacity were considered for possible clinical factors. In the stepwise multiple linear regression, the presence of ocular pathology, sex, age, and presence of cortical opacity were statistically significant factors influencing scores for some questions (Table 3). The scores for seeing strong light with type 1 illumination increased in the presence of cortical opacity ($P = .023$); scores for the same question with type 2 illumination decreased with age ($P = .043$); scores for feeling photophobia and scores for fright with type 1 illumination decreased in the presence of coexisting ocular pathology ($P = .004$ and $P = .006$, respectively); scores for seeing colors increased in women ($P = .034$); scores for the same question with type 2 illumination increased in the presence of coexisting ocular pathology ($P = .041$); scores for seeing instruments or surgical procedures with type 1 illumination increased in women ($P = .014$); scores for the same question with type 2 illumination decreased in the presence of coexisting ocular pathology ($P = .021$).

In the subgroup analysis, there were no significant differences between the 2 groups in age, sex, and the specific type of cataract. However, the prevalence of coexisting ocular pathology was higher in the type 1 group ($P = .059$) (Table 4). Logistic regression showed a similar result; patients with coexisting ocular pathology were more likely to prefer type 1 illumination (odds ratio, 0.240; 95% confidence interval, 0.058-0.99) ($P = .049$).

Some patients were asked to draw what they experienced. Two patients who remembered their surgery exactly and recalled as many details as possible shared their personal experience (Figure 3). The drawing in Figure 3, *A*, was perceived by a 65-year-old woman who had cataract surgery under sub-Tenon anesthesia. When looking up at the microscope light (*a*), where she saw 2 circles separated by a space, she felt severe photophobia and thought it would be very hard to perform the surgery. In the microscope lighting, her surgical field appeared as a light-colored image, as if she were underwater, and she could not see any details. However, when looking up in the intracameral lighting (*b*), which was soft ambient lighting, she became more comfortable without any glare and discomfort. She could see instruments and surgical procedures such as phacoemulsification and irrigation/aspiration more clearly. The drawing in Figure 3, *B*, was perceived by a 46-year-old woman who had cataract surgery under sub-Tenon anesthesia. The patient reported seeing not only a lump or particles of the lens being divided and aspirated through the opening of the instrument, but also the intraocular fluid being sucked into the opening. The patient's view seemed similar to the surgeon's view. However, it was determined that although the patient had difficulty opening her eyes under the microscope light, she could open her eyes and fixate when the surgeon was performing surgery under the intracameral light.

Table 1. Patient demographics (N = 60).

Parameter	Value
Sex, n (%)	
Male	26 (43.3)
Female	34 (56.7)
Age (y)	
Mean ± SD	62.27 ± 9.8
Range	40, 85
Operated eye, n (%)	
Right	24 (40)
Left	36 (60)
Characteristics of cataract	
NS grade	
Mean ± SD	2.12 ± 1.0
Range	0, 5
Presence of CO, n (%)	40 (66.7)
Presence of ACO, n (%)	3 (5)
Presence of PSCO, n (%)	35 (58.3)
Coexisting ocular pathology, n (%)	
Yes	30 (50)
No	30 (50)
CDVA 1 mo postop	
Mean ± SD	0.87 ± 0.2
Range	0.3, 1.0

ACO = anterior cortical opacity; CDVA = corrected distance visual acuity; CO = cortical opacity; NS = nuclear sclerosis; PSCO = posterior subcapsular opacity

Model Eye

In the model eye, the cataractous lens fragments were clearly seen with the surgical microscope both by the coaxial illumination from the microscope and by the oblique intracameral illumination (Figure 4). The lens fragments were illuminated uniformly by the coaxial illumination of the microscope but the sides of the lens fragments toward the light pipe were illuminated brighter with oblique intracameral illumination. From the rear view of the model eye with the coaxial light of the microscope, the lens fragments were seen as black material-like shadows. The coaxial light of the microscope was seen as the bright light in the center. In contrast, the lens fragments were seen as obscure white masses and the light of the light pipe was seen as a bright light from the periphery. The camera setting was f4 and the shutter speed was 1/400 with the coaxial microscope illumination and 1/125 to 1/200 with the intracameral illumination, indicating that the light exposure to the retina in the intracameral illumination was approximately 30% to approximately 50% of that in the microscope illumination.

DISCUSSION

Light damage to the macula during cataract surgery has been well documented.[9] In 1995, the U.S. Food and Drug Administration issued a public health advisory[10] about retinal photic injuries from operating microscopes during cataract surgery. The operating microscope manufacturers have since incorporated ultraviolet and infrared filters to minimize the possibility of phototoxic damage. However, intraoperative microscope light-induced photochemical damage can be caused by radiation between 400 nm and 550 nm, still opening the possibility of photochemical insult to the retina.[11,12] Advances in operating microscope systems and surgical techniques have reduced but not eradicated the phototoxicity rate. Many subclinical or mild microscope light-induced retinal injuries, such as delayed visual recovery[5,13] or temporary loss of blue cone response,[14] probably remain undiagnosed in routine postoperative examinations. The incidence of transient macular photochemical injuries that cause temporary visual disturbances in patients has not been described in the literature. The time and intensity of the coaxial illumination should be minimized. To attenuate macular light irradiation during cataract surgery, safety measures, such as tilting the microscope beam away from the fovea or the night-vision system using a near-infrared operating microscope, have been introduced.[5,13,15]

In terms of efficiency, the intracameral illumination provides less cornea/sclera reflection and scatter, more contrast and depth, and more dynamic lighting than the microscope illumination.[1–4] Changing to the new system might be comparable to upgrading from standard-definition television to high-definition television. The use of the endoilluminator and the decreased field of view in the intracameral illumination might be unsettling for some cataract surgeons initially because they have been accustomed to the view offered by the microscope illumination. Subjectively, however, the field of view with the intracameral illumination is more than sufficient to safely perform cataract surgery. Surgeons might find it takes a few cases to fully adapt to the new view. Because of the improved visualization of the new system, surgeons might be more comfortable during the surgery. In addition, the

Table 2. Comparison of questionnaire scores after using microscope illumination (type 1) or intracameral illumination (type 2).

	Type 1 Illumination Score		Type 2 Illumination Score		
Question	Mean ± SD	Range	Mean ± SD	Range	*P* Value*
1. Seeing strong light	6.87 ± 2.1	1, 10	4.00 ± 2.6	0, 10	<.001
2. Feeling photophobia	5.59 ± 2.6	0, 10	2.52 ± 1.9	0, 9	<.001
3. Feeling fright when seeing lights	4.65 ± 2.2	0, 10	2.20 ± 1.6	0, 6	<.001
4. Seeing any colors	5.08 ± 2.2	1, 9	3.67 ± 2.7	0, 9	<.001
5. Seeing any instruments or surgical procedures	3.58 ± 2.8	0, 9	4.45 ± 2.9	0, 9	.085
6. Estimating intraoperative visual function	4.32 ± 1.8	1, 9	3.88 ± 2.3	0, 10	.078

*Paired *t* test

Table 3. Potential risk factors associated with each score of the questionnaire and illumination type; results of the multiple linear regression analysis.

Dependent Variables Question/Illumination Type	Independent Variables	β	Standard Error	*P* Value	R^2
1. Strong lights					
Type 1	Constant	6.00	0.45	<.001	0.086
Type 1	Presence of CO	1.30	0.55	.023	
Type 2	Constant	8.27	2.09	<.001	0.069
Type 2	Age	−0.07	0.03	.043	
2. Photophobia					
Type 1	Constant	6.53	0.45	<.001	0.132
Type 1	Coexisting ocular pathology	−1.88	0.63	.004	
Type 2	None	—	—	—	—
3. Fright					
Type 1	Constant	5.43	0.39	<.001	0.125
Type 1	Coexisting ocular pathology	−1.57	0.55	.006	
Type 2	None	—	—	—	—
4. Colors					
Type 1	Constant	5.62	0.37	<.001	0.075
Type 1	Male sex	−1.23	0.57	.034	
Type 2	Constant	2.97	0.47	<.001	0.070
Type 2	Coexisting ocular pathology	1.40	0.67	.041	
5. Instruments					
Type 1	Constant	4.35	0.46	<.001	0.100
Type 1	Male sex	−1.78	0.70	.014	
Type 2	Constant	5.30	0.51	<.001	0.088
Type 2	Coexisting ocular pathology	−1.70	0.72	.021	
6. Estimating visual function					
Type 1	None	—	—	—	—
Type 2	None	—	—	—	—

ACO = anterior cortical opacity; β = unstandardized regression coefficient; constant = intercept of the regression model representing the mean score when the other variables take the value zero; CO = cortical opacity; PSCO = posterior subcapsular opacity; type 1 = microscope illumination; type 2 = intracameral illumination

insertion and movement of an endoilluminator into the anterior chamber might increase the risk for a tear in the Descemet membrane at the entry site or zonular dehiscence. Nonetheless, because the pipe length introduced into the eye was quite short and was controlled by experienced cataract surgeons, no complications were observed in our previous and current studies.[2,3]

Safety must be considered with any change in cataract surgery technique. However, there are only a few studies that show that the intracameral illumination system is safer for patients.[3,16,17] Because subjective visual experience during cataract surgery using microscope illumination might seem startling to a significant proportion of patients, any change that can reduce the fright will help improve patient outcomes

Table 4. Comparison of patient demographics according to the type of preferred illumination.

Parameter	Preferred Illumination: Type 1 (n = 13)	Preferred Illumination: Type 2 (n = 45)	*P* Value
Male sex, n (%)	7 (53.8)	27 (60)	.692*
Mean age (y) ± SD	63.15 ± 8.2	61.56 ± 11.0	.681†
Right operated eye, n (%)	5 (38.5)	18 (40)	.920*
Coexisting ocular pathology	10 (76.9)	20 (44.4)	.059*
Characteristics of cataract			
Mean NS grade ± SD	2.23 ± 1.3	2.09 ± 0.9	.655†
Presence of CO, n (%)	8 (61.5)	31 (68.9)	.619*
Presence of ACO, n (%)	0 (0)	3 (0.07)	1.000*
Presence of PSCO, n (%)	8 (61.5)	27 (60)	.920*
Mean CDVA ± SD 1 mo postop	0.92 ± 0.1	0.85 ± 0.2	.274†

ACO = anterior cortical opacity; CDVA = corrected distance visual acuity; CO = cortical opacity; NS = nuclear sclerosis; PSCO = posterior subcapsular opacity; type 1 = microscope illumination; type 2 = intracameral illumination
*Chi-squared test
†Independent *t* test

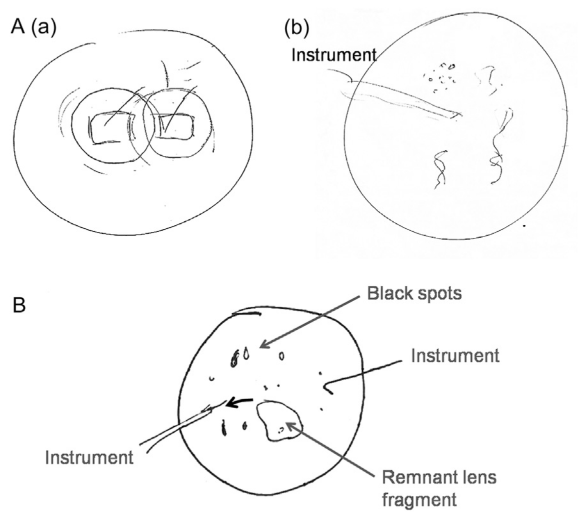

Figure 3. *A*: Drawings perceived by a 65-year-old woman who had cataract surgery under sub-Tenon anesthesia when looking up at the microscope light (*a*) and when looking up in the intracameral lighting (*b*). *B*: A drawing perceived by a 46-year-old woman who had cataract surgery under sub-Tenon anesthesia.

and satisfaction with the surgery.[8,18,19] Therefore, we should consider patient discomfort and macular photic stress associated with microscope illumination versus intracameral illumination during phacoemulsification cataract surgery.

The following are our main findings in this study. First, subjective macular photostress was more severe under microscope illumination than under intracameral illumination during phacoemulsification cataract surgery. When patients view a light source that is sufficiently bright during surgery, they might experience visual discomfort.[8,18,19] Intraoperative visual discomfort refers to a subjective perceptual experience that is dependent on the patient's response criterion. Based on the model-eye experiment, macular illuminance with the microscope light, rather than extramacular illuminance with the intracameral light, was more closely related to patient discomfort and macular photostress. The degree of visual discomfort or photostress during surgery might be predicted based on excessive local photopigment bleaching in brilliant light exposures.[20] The findings from this study suggest that photoreceptor saturation in the macula plays an essential part in determining visual discomfort or photostress.

Second, patients saw more colors and the self-assessment of intraoperative visual function was better with microscope illumination than with intracameral illumination. In photopic conditions under the microscope lighting, the surgical field might appear as a more-colored image, which is perceived mainly by the cone system, whereas in mesopic or scotopic conditions under the intracameral lighting, the field might be a less-colored image, which is perceived

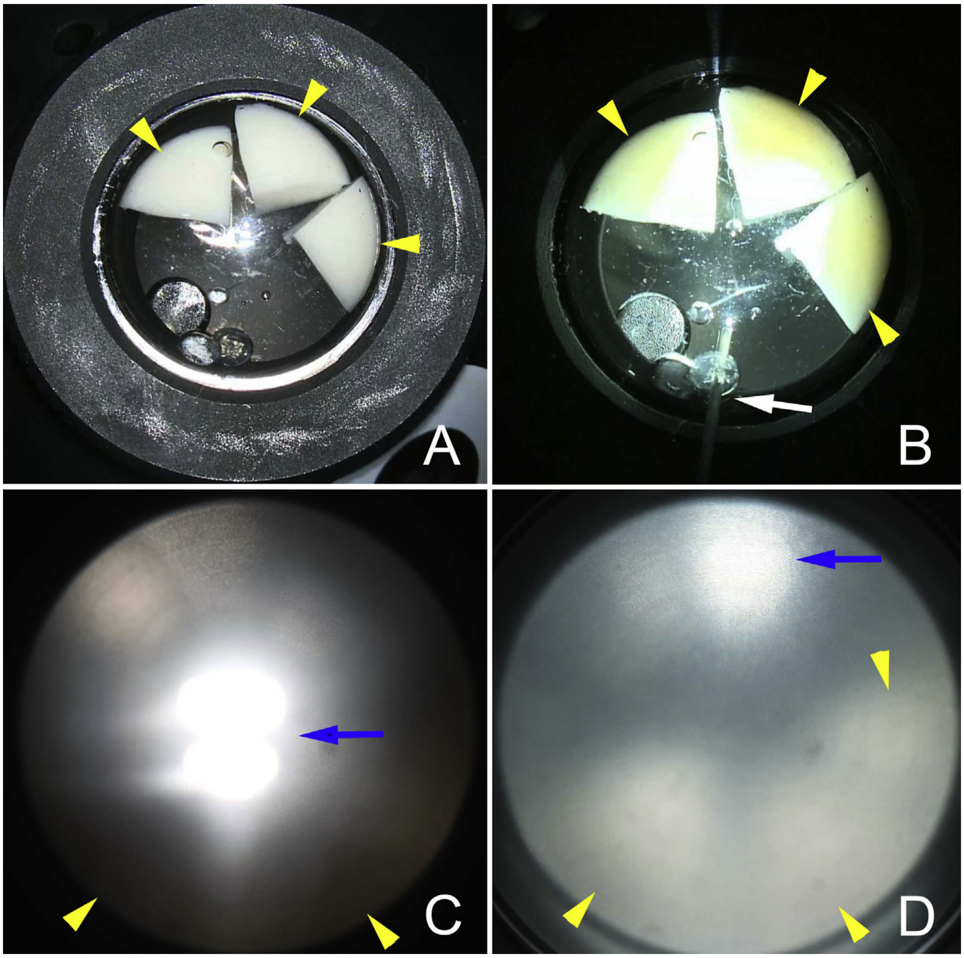

Figure 4. Images of the model eye with cataractous lens fragments in the anterior chamber (*upper column*: surgeon's view with microscope; *lower column*: rear view of the model eye). *A*: Lens fragments (*yellow arrowheads*) placed in the anterior chamber of the model eye are illuminated uniformly by the coaxial illumination of the microscope. *B*: Sides of the lens fragments (*yellow arrowheads*) toward the light pipe (*arrow*) are illuminated brighter by the intracameral illumination. *C*: Shadows of the lens fragments (*yellow arrowheads*) are seen under the bright light (*blue arrow*) of the microscope. *D*: Lens fragments (*yellow arrowheads*) are seen as white mass with the light of the light pipe (*blue arrow*).

mainly by the rod system. Because daylight vision is usually better than night vision in humans, the patients might have estimated better intraoperative visual function under the microscope illumination. However, because the actual view or visibility perceived by patients is highly associated the intraoperative macular function, the visibility of the images of the surgical procedures and the instruments inserted into the anterior chamber was better under intracameral illumination. This finding was consistent with the model-eye experiment. The photostress and risk for macular phototoxicity might be greater with microscope lighting than with intracameral lighting.

Third, most patients preferred intracameral illumination to microscope illumination. Patients' satisfaction and surgical outcomes are determined by the ability to perform surgery efficiently and safely. This result suggests that cataract surgery using this new illumination system is more efficient and safer than the standard cataract surgery using a traditional coaxial illumination.

Fourth, patients with coexisting ocular pathology had lower macular photostress scores and preferred the microscope illumination to intracameral illumination more than patients without coexisting ocular pathology. Because of already decreased retinal or macular function in patients with coexisting ocular pathology, the sensitivity or discomfort to the bright light of the microscope might have been decreased. However, because patients with retinal diseases would show a high susceptibility to retinal light damage,[15] a modification of the lighting such as intracameral illumination should be considered to minimize the risk for photochemical retinal damage.

Many variables in cataract surgery can influence the patient's macular strain and function intraoperatively. Because discomfort threshold (photosensitivity) reflects a subjective perceptual experience, there have been large interindividual variations in the thresholds in previous reports in the peer-reviewed literature.[20,21] Furthermore, in intereye studies, recall might influence a patient's perception of discomfort or pain during consecutive cataract surgeries and this could be altered depending on the timing of questionnaire administration, the effects of sedation, or the common phenomenon that a memory of an event is distorted over time.[22,23] Therefore, we tried to minimize these variables as much as possible with an intraindividual intraeye study design.

The limitations of this study are the absence of other objective assessments of macular photostress such as immediate postoperative visual recovery.[5,13] We could not measure and compare visual acuity or visual recovery time. Although cataract surgery using the intracameral illumination system might be more efficient and safer than standard cataract surgery, we acknowledge that an installation of the illumination system into current cataract setups (ie, conventional phacoemulsification machine without a self-illumination system) is necessary for its universal application. Further studies should also be performed to provide long-term safety and efficacy of this new system.

In conclusion, patients during cataract surgery experienced less bright light and were more comfortable with intracameral illumination than with microscope illumination. The images created in the model eye correlated with the patients' visual experiences. In terms of safety and efficiency, this new intracameral illumination system could represent an alternative solution in the effort to minimize phototoxicity to the macula during cataract surgery.

WHAT WAS KNOWN

- Coaxial microscope illumination has been the standard visualization method in cataract surgery. However, it provides limited visualization in some advanced cases and it sometimes leads to patient discomfort or fear during the surgery.

WHAT THIS PAPER ADDS

- A new intracameral illumination system introduced by this study group provided real-time high-quality lens images, in particular in eyes with corneal opacity, a small pupil, or advanced cataract.
- The intracameral illumination system provided good visualization for the surgeon as well as comfort and safety for the patient, especially in terms of macular phototoxicity during cataract surgery.

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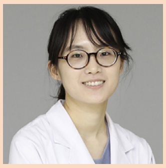

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