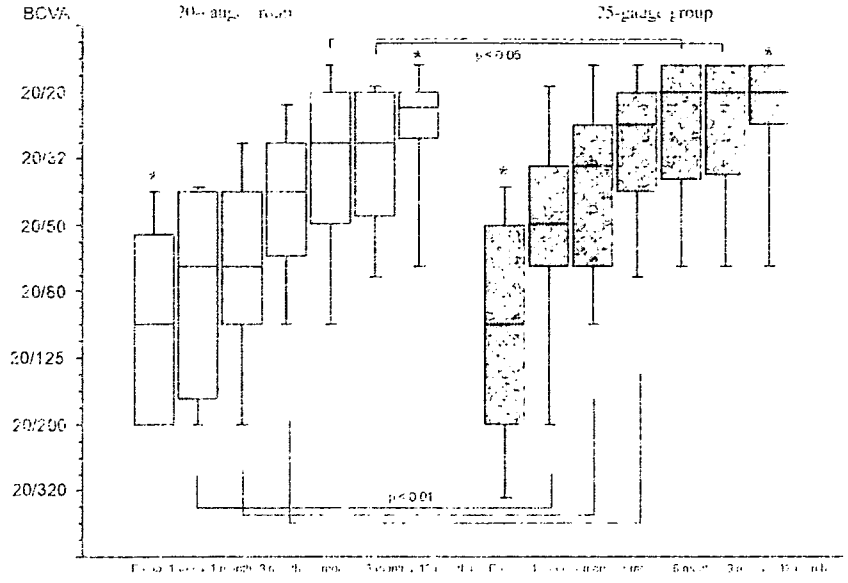

Fig. 1. Mean pre- and postoperative best corrected visual acuity (BCVA). Postoperative BCVA is significantly better than preoperative BCVA in the 25-G group at 1 week and at 1, 3, 6 and 9 months, but not at 12 months ($p < 0.05$, unpaired *t*-test). * Not significant.

Table 2. Post-surgery visual improvement in logMAR units.

Visual acuity	25-G group	20-G group	p-value*	p-value†	p-value‡	p-value§
Preoperative	0.72 ± 0.36	0.68 ± 0.27				
Postoperative						
1 week	0.40 ± 0.34	0.58 ± 0.30	0.020			
1 months	0.28 ± 0.27	0.49 ± 0.29	0.001	0.499		
3 months	0.18 ± 0.25	0.34 ± 0.27	0.004	0.794	0.245	
6 months	0.11 ± 0.25	0.25 ± 0.31	0.023	0.511	0.265	0.344
9 months	0.10 ± 0.24	0.23 ± 0.27	0.032	0.531	0.080	0.146
12 months	0.09 ± 0.23	0.15 ± 0.27	0.182	0.086	0.011	0.004

* p-value by comparison with preoperative vision according to unpaired *t*-test.
† p-value by comparison with postoperative VA at 1 week according to unpaired *t*-test.
‡ p-value by comparison with postoperative VA at 1 month according to unpaired *t*-test.
§ p-value by comparison with postoperative VA at 3 months according to unpaired *t*-test.
VA = visual acuity.

postoperative VA in logMAR units improved to 0.28 ± 0.27 in the 25-G group and 0.49 ± 0.29 in the 20-G group. The improvement in BA was significantly better at both time-points in the 25-G group ($p = 0.020$, $p = 0.001$, respectively). This significant difference in visual improvement was maintained at 3, 6 and 9 months after surgery ($p = 0.004$, $p = 0.023$, $p = 0.032$, respectively), but, at 12 months, the visual improvement did not differ significantly between the two groups ($p = 0.182$). However, VA at 12 months compared with postoperative VA at 1 and 3 months was significantly better in the 20-G group than in the 25-G group ($p = 0.011$, $p = 0.004$, respectively) (Fig. 1, Table 2). This significant difference indicated that the visual improvement in 25-G group was achieved during an earlier postoperative period (from 1 week to 3 months), but not from 6 to 12 months.

Postoperative VA > 20/20 was achieved in 15 eyes (65%) in the 25-G group and 10 eyes (43%) in the 20-G group ($p = 0.139$) (Fig. 2). Postoperative VA > 20/25 was achieved in 18 eyes (78%) in the 25-G group and 16 eyes (70%) in the 20-G group ($p = 0.502$).

Operating time and volume of irrigating fluid

Table 3 shows operating time and volume of intraocular irrigating fluid for each group. Operating time was significantly shorter in the 25-G group ($p = 0.003$). Operating time in patients who underwent simultaneous cataract surgery was also significantly shorter in the 25-G group than in the 20-G group ($p = 0.002$). Operating time in the patients who did not undergo simultaneous cataract surgery was also significantly shorter in the 25-G group ($p = 0.049$).

The volume of intraocular irrigating fluid in the 25-G group was significantly less than in the 20-G group ($p < 0.0001$). The volume of intraocular irrigating fluid in patients who underwent simultaneous cataract surgery in the 25-G group was significantly less than that in the 20-G group ($p < 0.0001$). The volume of intraocular irrigating fluid used in patients who did not have simultaneous cataract surgery in the 25-G group was also significantly less than that in the 20-G group ($p = 0.006$).

Surgery-induced astigmatism and intraoperative retinal breaks

The mean surgery-induced astigmatism in the 25-G group was 0.39 ± 0.30 dioptres (D) at postoperative week 1, 0.43 ± 0.29 D at 1 month, 0.36 ± 0.33 D at 3 months; parallel figures for the 20-G group were 0.88 ± 0.71 D, 0.54 ± 0.48 D and 0.52 ± 0.49 D, respectively (Fig. 3). Surgery-induced astigmatism was significantly lower in the 25-G group at postoperative week 1 ($p = 0.009$, unpaired *t*-test), but not at 1 and 3 months ($p = 0.391$, $p = 0.272$, respectively; unpaired *t*-test).

Peripheral retinal breaks were found intraoperatively in four eyes (17%) in the 25-G group and five eyes (22%) in the 20-G group ($p = 0.710$) (Table 3). However, none of the eyes in the 25-G group developed retinal breaks related to the sclerotomy, whereas three eyes (13%) in the 20-G group did, although this was not significant ($p = 0.073$).

Discussion

Our results showed that the vitrectomy performed with the 25-gauge system led to significantly better VA during the first 9 months after surgery than conventional 20-G vitrectomy. However, at 12 months, VAs were not significantly different with the two

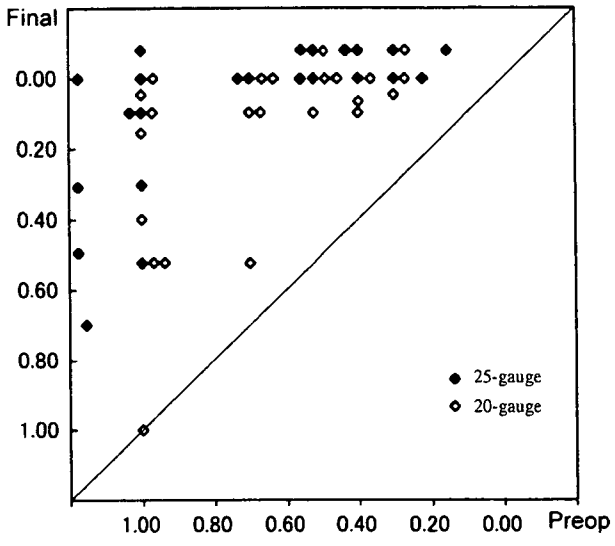

Fig. 2. Preoperative and final best corrected visual acuity (BCVA). The differences in numbers of eyes with postoperative BCVA > 20/20 and > 20/25 were not significant in the two groups (p = 0.183, p = 0.889, respectively; chi-square test).

Table 3. Operating time and volume of intraocular irrigating fluid in both groups.

	25-G group	20-G group	p-value
Operating time (mins)	56 ± 16	85 ± 28	0.003*
With cataract surgery	58 ± 16	90 ± 30	0.002*
Without cataract surgery	42 ± 14	64 ± 7	0.049*
Volume of intraocular irrigating fluid (ml)	244 ± 72	416 ± 113	< 0.0001*
With cataract surgery	258 ± 60	450 ± 100	< 0.0001*
Without cataract surgery	110 ± 14	281 ± 24	0.006*
Eyes with peripheral retinal breaks	4 (17%)	5 (22%)	0.710†
Eyes with sclerotomy-related retinal breaks	0 (0%)	3 (13%)	0.073†

* p-value according to unpaired *t*-test.
† p-value according to chi-square test.

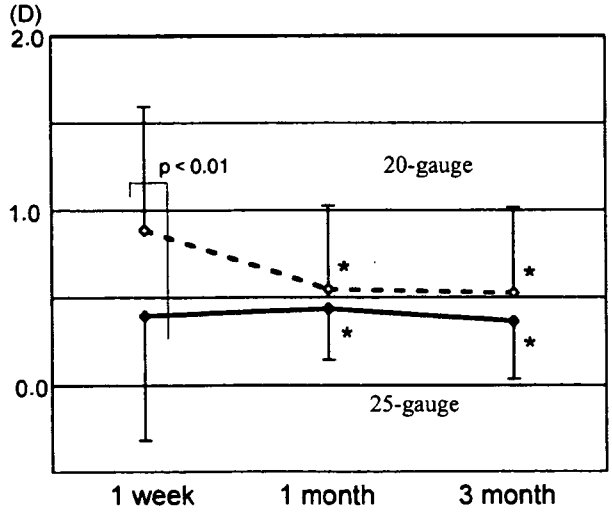

Fig. 3. Postoperative surgery-induced astigmatism. Surgery-induced astigmatism was significantly less in the 25-G group at postoperative week 1 (p = 0.009, unpaired *t*-test), but the difference between the two groups was not significant at 1 and 3 months (p = 0.391, p = 0.272, unpaired *t*-test). * Not significant.

vitrectomy systems. Kadonosono et al. (2006) reported better VA after 25-G vitrectomy than after the 20-G procedure at 1 month but not at 6 months for patients with an epiretinal membrane (ERM). Rizzo et al. (2006) reported rapid visual improvement and less postoperative discomfort after 25-gauge vitrectomy, with shorter surgical time and less intraoperative use of BSS in patients with an ERM.

Our patients underwent macular hole surgery, which required more complicated surgical procedures than does surgery for ERM, such as the thorough removal of peripheral vitreous, subsequent gas tamponade and facedown positioning. This would suggest that 25-G vitrectomy results in better visual outcomes during the early period after more complicated surgery.

The better results observed with 25-G vitrectomy may be partly explained by the fact that it requires less irrigating fluid and surgical time. Negi et al. (1981) reported a decrease in the amplitudes of electroretinograms (ERGs) after intraocular irrigation with Ringer's solution or BSS in rabbit eyes, although the reduction was smaller than that after irrigation with physiological saline. When retinal oedema was induced by perfusion with different intraocular solutions for different durations in albino rabbits, Ringer's lactate and physiological saline solutions were reported to lead to more oedema than BSS-plus and the induced oedema was more severe with longer perfusion times (Saornil Alvarez & Pastor Jimeno 1987). In addition, intraocular irrigating solution at operating room temperature has been reported to decrease the temperature in the human vitreous cavity to 27–28 °C, which led to markedly delayed peak time latencies and reduced ERG amplitudes, although the functional changes were reversible (Horiguchi & Miyake 1991). Thus, the reduction in the volume of intraocular irrigating fluid and the duration of irrigation may minimize the surgical invasiveness of 25-G vitrectomy, as is supported by our results.

The surgery-induced astigmatism was also significantly lower in the 25-G group at postoperative week 1, but not at 1 and 3 months. Better visual recovery after 25-gauge vitrectomy may also be related to the lower

postoperative astigmatism, especially in the short term. However, further studies should be performed to evaluate the efficacy of 25-gauge vitrectomy because most of our cases involved simultaneous cataract surgery.

One other advantage of 25-G vitrectomy concerns the size of the cannula, which reduced the incidence of sclerotomy-related retinal breaks (Machemer & Hickingbotham 1985; Territo et al. 1997). In our study, none of the eyes in the 25-G group developed sclerotomy-related retinal breaks, although three eyes in the 20-G group developed retinal breaks ($p = 0.073$). Scartozzi et al. (2007) described a tendency towards a lower incidence of intraoperative sclerotomy-related retinal breaks, single or multiple, with 25-gauge vitrectomy compared with 20-gauge vitrectomy for macular surgery, but the differences were not significant. When iatrogenic retinal breaks are found, careful vitreous shaving around the retinal breaks and additional surgical procedures including endophotocoagulation under fluid–air exchange are mandatory. This leads to an increase in operating time and volume of intraocular irrigating fluid. It may also increase the risk of temporal visual field defects after retinal dehydration by air infusion (Kerrison et al. 1997).

Thus, 25-gauge vitrectomy has several advantages: it is less invasive to the ocular surface; requires less surgical time, and uses a lower volume of irrigating fluid. All of these differences benefit the ocular surface and the neural retina, which may then result in better and earlier functional recovery after surgery.

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25-Gauge Cannula System with Microvitreoretinal Blade Trocar

Makoto Inoue, Kei Shinoda, Hajime Shinoda, Kotaro Suzuki, Ryosuke Kawamura, and Susumu Ishida

PURPOSE: To report a 25-gauge trocar-cannula that enhances wound closure and reduces the incidence of postoperative hypotony.

DESIGN: Development of surgical instruments.

METHODS: A 25-gauge cannula with a microvitreoretinal (MVR) blade trocar was constructed. The resistance of inserting this trocar cannula was compared with that of the conventional 25-gauge trocar cannula (Alcon Laboratories; Fort Worth, Texas, USA). Vitreous surgery was performed on 55 eyes with the trocar cannula with an oblique sclerotomy incision, and the results were compared with those from 68 eyes that underwent surgery with the conventional trocar cannula.

RESULTS: The resistance of inserting the trocar cannula was less than that with the conventional trocar cannula. A temporary hypotony (intraocular pressure [IOP] <6 mm Hg) was found in one eye (2%) with the trocar cannula and in 12 eyes (18%) with the conventional trocar cannula ($P = .006$, Fisher exact probability test).

CONCLUSIONS: The trocar cannula with a MVR blade was effective in postoperative wound closure and prevention of postoperative hypotony. (Am J Ophthalmol 2007; 144:302–304. © 2007 by Elsevier Inc. All rights reserved.)

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TRANSCONJUNCTIVAL VITRECTOMY SYSTEM WAS DEVELOPED to permit transconjunctival sutureless vitrectomy;[1] however, hypotony, endophthalmitis, and choroidal detachments have been reported as postoperative complications.[2] Oblique sclerotomy and scleral tunnel incisions were reported to minimize the incidence of wound leakage.[3,4] However, we hypothesized that a slit-shaped incision by a microvitreoretinal (MVR) blade would enhance the sutureless wound closure.[5] Thus, we designed a trocar cannula with an MVR blade as the trocar to determine whether this system will have lower resistance during insertion and will enhance wound closure, preventing postoperative hypotony.

The trocar cannula was designed to have an MVR blade trocar (Figure 1). The width of the MVR blade is 0.50 mm and the inner diameter of the cannula is 0.52 mm. The resistance of inserting the trocar cannula through the enucleated porcine sclera was measured by a TENSILON Universal Tensile Instrument (n = 2; RTC-1250A, A&D Company, Tokyo, Japan). The values were compared with those of the conventional needle-shaped 25-gauge trocar system (Alcon Laboratories; Fort Worth, Texas, USA).

Vitrectomy was performed on 55 eyes with the trocar cannula system after obtaining informed consent; the patients were followed up for at least three months. An oblique incision was made for the transconjunctival sclerotomy. The MVR blade trocar was pushed through the sclera tangentially at an angle 45 to 60 degrees (Figure 1). This direction was parallel to the corneal limbus, and the direction was altered to enter the center of the globe perpendicularly. At the end of the surgery, the cannula was removed, and the sclerotomy site was wiped gently with cotton swabs to close the opening.

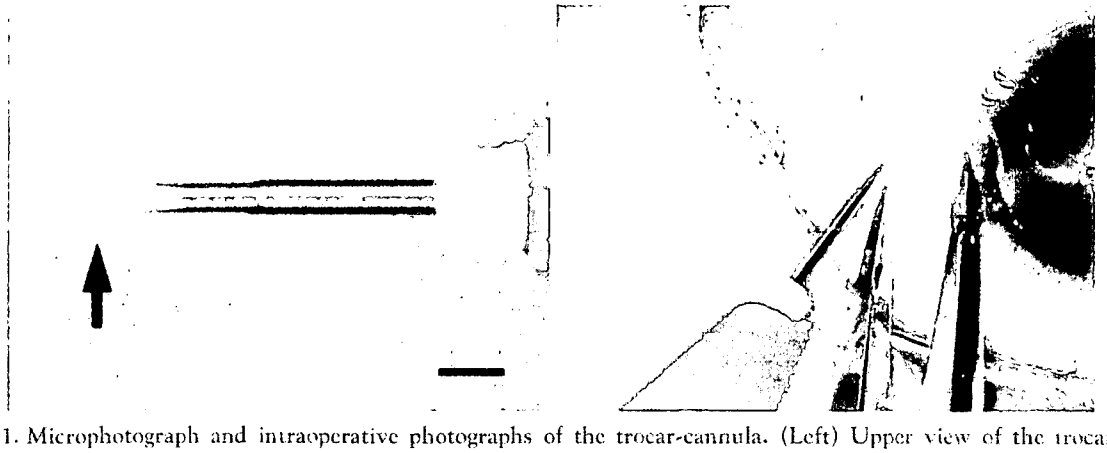

FIGURE 1. Microphotograph and intraoperative photographs of the trocar-cannula. (Left) Upper view of the trocar-cannula. Arrow points of the head of the trocar with a microvitreoretinal (MVR) blade (Bar = 0.5 mm). (Right) Initially, the head of the MVR blade trocar penetrates the globe tangentially at an angle of 45 degree and parallel to corneal limbus. Subsequently, the direction of the trocar is then modified vertically.

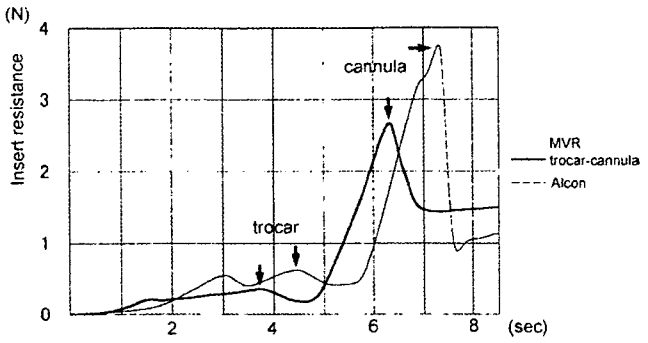

FIGURE 2. Graph demonstrating resistance of insertion of the trocar cannula through the porcine sclera. The resistance of insertion of the microvitreoretinal (MVR) trocar cannula was less than that of the conventional trocar cannula when both the trocar and the cannula were pushed through the sclera, as indicated by arrows.

The intraocular pressure (IOP) was controlled by injecting balanced salt solution into the anterior chamber or vitreous cavity.

These eyes were compared with 68 eyes that underwent vertical sclerotomy with a standard 25-gauge trocar cannula (Alcon Laboratories). The selection of the patients was not randomized and the methodology was unmasked. The IOPs were measured before surgery and after surgery on days one, two, and seven. The incidence of hypotony (IOP, <6 mm Hg) was determined. The inserting resistance of the trocar cannula though the porcine sclera was less than that of the conventional trocar cannula both when the trocar and the cannula were inserted (Figure 2). In patients, the trocar could be inserted easily through the sclera, and the cannula could be oriented as with other trocar cannula systems. The cannula was not retracted from the sclerotomy during the surgery, and sutures were not required in any cases.

The mean ± standard deviation preoperative IOP in the eyes on which the trocar cannula was used was 14.3 ± 2.9 mm Hg and the postoperative IOP was 13.8 ± 4.6 mm Hg on day 1, 13.1 ± 3.8 mm Hg on day 2, and 13.4 ± 3.3 mm Hg on day 7 (P = .891, .078, and .074, respectively, compared with preoperative IOP by Wilcoxon rank-sum test). A temporary hypotony (5 mm Hg) was found in one eye (2%), but this eye was being treated with anti-glaucoma eye drops for glaucoma before surgery (Table). The IOP gradually recovered after three days by temporary discontinuance of the anti-glaucoma drugs. A temporary hypotony was found in 12 eyes (18%) with the standard vitrectomy, which was significantly higher (P = .006, Fisher exact probability test). The incidence of hypotony

TABLE. Comparison of the 25-Gauge Microvitreoretinal Trocar Cannula Vitrectomy and the Standard 25-Gauge Vitrectomy

Surgical Procedure	Total Eyes with Postoperative Hypotony	Procedure (Eyes) with Postoperative Hypotony	No. of Eyes with Disease
25-gauge microvitreoretinal trocar-cannula vitrectomy	1/55 (2%)*	No exchange, 1/29 (3%)†	Macular hole, 13
		Gas exchange, 0/26 (0%)‡	Epiretinal membrane, 12
		Cataract surgery, 1/30 (3%)§	RVO, 9
		Vitrectomy alone, 0/25 (0%)‖	PDR, 6
		Previous vitrectomy, 0/1 (0%)¶	DME, 5
			Vitreous opacity, 5
			Uveitis, 4
			Retinal detachment, 1
Standard 25-gauge trocar-cannula vitrectomy	12/68 (18%)*	No exchange, 10/47 (21%)†	Macular hole, 8
		Gas exchange, 2/21 (10%)‡	Epiretinal membrane, 19
		Cataract surgery, 8/31 (26%)§	RVO, 5
		Vitrectomy alone, 2/37 (5%)‖	PDR, 11
		Previous vitrectomy, 0/5 (0%)¶	DME, 11
			Uveitis, 4
			Neovascular maculopathy, 4
			Retinal detachment, 4
			IOL dislocation, 2

DME = diabetic macular edema; IOL = intraocular lens; PDR = proliferative diabetic retinopathy; RVO = retinal vein occlusion.
*P = .006 (Fisher exact probability test).
†P = .044 (Fisher exact probability test).
‡P = .194 (Fisher exact probability test).
§P = .077 (Fisher exact probability test).
‖P = .490 (Fisher exact probability test).
¶P = .999 (Fisher exact probability test).

in the eyes without a gas tamponade also was significant (P .044; 3% vs 21%), but not in the eyes with a gas tamponade (P = 194; 0% vs 10%). Leakage of intraocular fluid, endophthalmitis, and retinal detachment were not observed in any eye of either group.

We conclude that this trocar cannula is effective in obtaining better wound closure and results in a significantly lower incidence of postoperative hypotony. The basis for the wound construction is similar to the 23-gauge vitrectomy, which creates a sclerotomy with a slit-shaped knife with the angle of 30 degrees and placement of cannula, but the angle of penetration in this trocar cannula was larger than that of the 23-gauge vitrectomy.[5] Because of the small numbers of cases, further studies are needed to evaluate the efficacy of this surgical instrument.

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Refractive Findings in Children with Astigmatic Parents: The Sydney Myopia Study

Jenny M. Ip, Annette Kifley, Kathryn A. Rose, and Paul Mitchell

PURPOSE: To examine the impact of parental astigmatism on astigmatic error and ocular biometric parameters in children.

DESIGN: Population-based cross-sectional study.

METHODS: Six-year-old children (n = 1,741; 78.9% response) and 12-year-old children (n = 2,367; 75.3% response) underwent a comprehensive eye examination, including cycloplegic autorefraction and ocular biometry. Astigmatism was determined in parents from spectacle prescriptions, which were supplied for 468 children.

RESULTS: The prevalence of astigmatism in six-year-old children with astigmatic parents was not significantly different from that of those without astigmatic parents (6.8% vs 2.8%); corresponding rates for 12-year-old children were 9.5% and 7.8% (both $P > .05$). No significant differences in mean cylinder and in ocular biometric parameters were observed between children with astigmatic parents and those with no astigmatic parents.

CONCLUSIONS: Parental astigmatism was not associated with a higher prevalence of childhood astigmatism and did not seem to have a significant impact on measures of ocular biometric parameters in children. (Am J Ophthalmol 2007;144:304–306. © 2007 by Elsevier Inc. All rights reserved.)

ASTIGMATISM OF AT LEAST 1 DIOPTER (D) IS RELAtively common in children[1] and is associated with meridional amblyopia and myopia.[2] Recent studies examined familial or genetic associations with astigmatism. Twin studies reported higher correlations for astigmatism or cylinder power among monozygotic than dizygotic twins,[3,4] and although segregation analysis has suggested a major autosomal dominant locus for astigmatism,[5] only modest familial aggregation has been reported.[6] In the current study, we aimed to examine the impact of parental astigmatism on the prevalence of astigmatism and on ocular biometric parameters in children.

The Sydney Myopia Study is a cross-sectional survey of children attending schools across the metropolitan area of Sydney, Australia. Study methods have been reported previously.[7] Briefly, 1,741 primary school children (predominantly 6 years of age; 78.9% of those eligible) and 2,367 secondary school children (predominantly 12 years of age; 75.3% of those eligible) underwent a comprehensive eye examination. Parents completed a detailed questionnaire that included medical and obstetric questions; those reporting use of spectacles were asked to provide current prescriptions.

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Letters to the Editor

Intraoperative dehiscence of laser subepithelial keratomileusis (LASEK) flap during retinal detachment surgery

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Editor,

A 21-year-old man consulted us for refractive surgery even though his corrected visual acuity was 20/16 with a correction of −6.0 dioptres (D) in both eyes. The anterior segment and lens were clear and the fundus of the left eye was normal except for lattice degeneration. In the right eye, however, a localized peripheral retinal detachment of < 2 disc diameters (DDs) was present in the superior temporal quadrant with lattice degeneration in the nasal hemisphere. The patient was not aware of the retinal detachment. After discussing the risk of an extension of the retinal detachment, the patient declined retinal attachment surgery and selected to proceed with the refractive surgery. A signed informed consent was obtained, and LASEK was performed on both eyes. At 3 weeks, his uncorrected visual acuity had improved to 20/13 with a +0.25 D refractive error in both eyes. However, the retinal detachment had expanded inferiorly towards the macula but he remained asymptomatic at 4 months after the LASEK.

After explaining the changes in the retinal detachment and probable consequences, the patient agreed to scleral buckling surgery. The scleral buckling surgery, including cryopexy and a local buckle, was performed 5 months after the LASEK. Laser photocoagulation of the lattice degeneration was performed prior to the surgery to avoid the necessity of an encircling buckle. Although special attention was paid to avoid dehiscence of the LASEK flap, the corneal epithelium within the borders of the LASEK flap detached in the middle of the surgery. A bandage contact lens was applied at the end of the surgery to protect the denuded corneal epithelium and reduce pain.

Examination 6 days later showed that the retina was successfully reattached, and the corneal defect was completely resolved without haze. The uncorrected visual acuity recovered to 20/16 after 8 days. No significant change of corneal topography (ORB-SCAN, Bausch-Lomb, Rochester, New York, USA) was detected postoperatively, and the refraction remained at +0.25 D.

Postoperative retinal detachments have been reported following radial keratectomy, photorefractive keratectomy (PRK) and laser *in situ* keratomileusis (LASIK) (Ruiz-Moreno et al. 1999; Aras et al. 2000; Arevalo et al. 2001). Intraoperative dehiscence of the LASIK flap has developed during a buckling surgery 7 months after LASIK (Sakurai et al. 2002). Symptoms of dry eye and the recurrent erosion syndrome have been reported to develop more than 6 months after LASIK or PRK (Hovanesian et al. 2001). This would indicate that the corneal epithelial damage after refractive surgery might require a long time for complete recovery (Hovanesian et al. 2001). The incidence of eyes with eyelid adhesion and sharp pain as well as the severity of sharp pain was reported to be significantly higher in PRK patients than in LASIK patients. The absence of tight adhesions of the corneal epithelial cells to the corneal surface after refractive surgery may be similar to the recurrent corneal erosions after a traumatic abrasion of the cornea. Removal of Bowman's membrane may be the cause of the absence of tight adhesions of the corneal epithelium after PRK and LASEK surgery.

The refractive changes are important to consider when treating patients for complications after refractive surgeries. Myopic changes have been induced by scleral buckling in patients with retinal detachment after LASIK from −0.58 D preoperatively to −2.25 D postoperatively (Ruiz-Moreno et al. 1999). In our case, the scleral buckling did not alter the refractive error. However, the refraction in such an eye can change after scleral buckling surgery or vitrectomy and the following cataract operation might obviate the need for refractive surgery. Thus, the refractive surgery should not be performed even in an eye of asymptomatic retinal detachment with possible extension of the detachment.

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Letter to the Editor

Residual crystals of triamcinolone acetonide in macular hole may prevent complete closure

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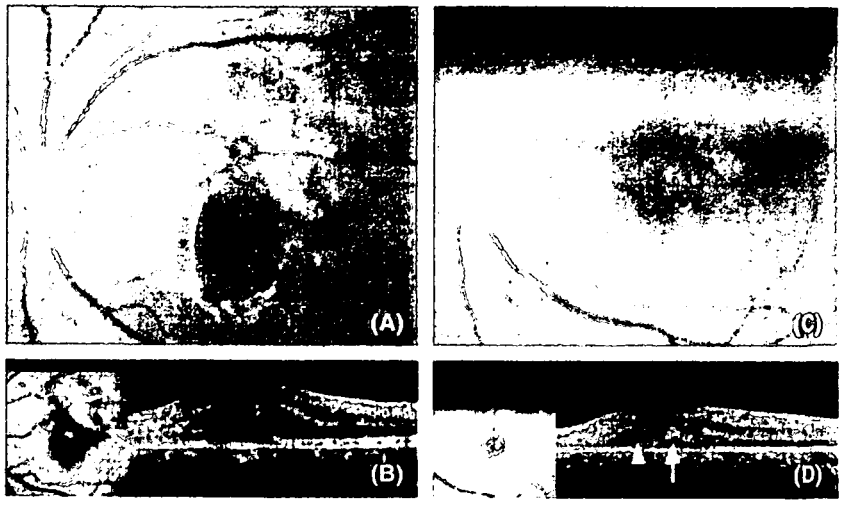

Fig. 1. (A) Fundus photograph and (B) optical coherence tomography (OCT) image in the left eye, 10 months after blunt trauma, showing a full-thickness macular hole (MH). (C) Fundus photograph 4 days after the initial surgery, showing residual white crystals of triamcinolone acetonide (TA) in the MH. (D) OCT image at the same location, showing a flattened MH with remaining cysts (white arrowhead). The strong signals in the MH are caused by TA crystals (white arrow).

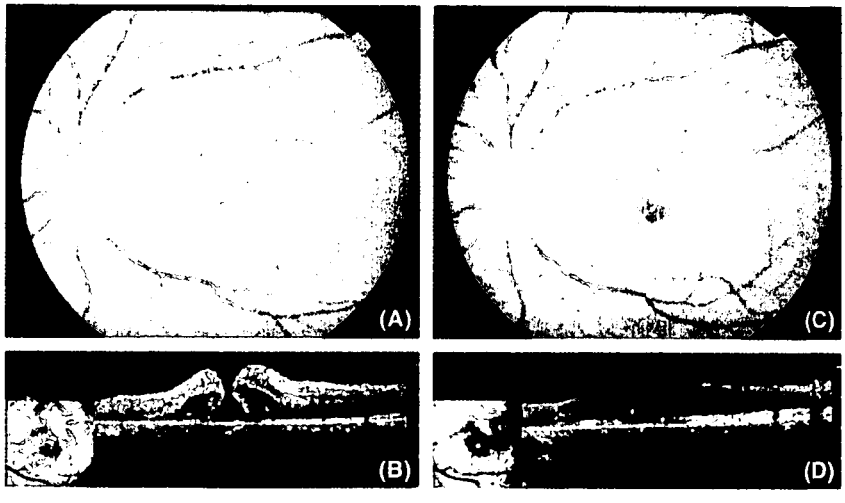

Fig. 2. (A) Fundus photograph and (B) optical coherence tomography (OCT) image in the left eye, 2 weeks after surgery, showing the reopening of the macular hole (MH) after the disappearance of residual white crystals of triamcinolone acetonide in the MH. (C) Fundus photograph and (D) OCT image after additional gas tamponade, showing the successful closure of the MH 2 months after the initial surgery.

Editor,

Triamcinolone acetonide (TA) is used during pars plana vitrectomy to make the transparent vitreous and internal limiting membrane (ILM) more visible, which aids in creating a posterior vitreous detachment and in peeling the ILM (Peyman et al. 2000; Kimura et al. 2004). Successful closure of a macular hole (MH) has been described even when TA crystals remain in the MH postoperatively (Takeuchi et al. 2003; Yamauchi et al. 2006). However, residual TA crystals in the MH may affect closure of the MH.

We describe a patient with a traumatic MH that did not close completely after conventional vitrectomy. Residual TA crystals were detected in the flattened MH.

A 12-year-old boy complained of visual difficulties that had begun 10 months earlier after he had been hit in the left eye by a soccer ball. No visual impairment had been detected immediately after the trauma, but the subject's best corrected visual acuity was 20/60 in the affected eye. Ophthalmoscopy and optical coherence tomography (OCT) revealed an MH and chorioretinal atrophy close to the MH (Fig. 1A, B).

Informed consent was obtained and vitrectomy was performed 2 months after the first visit. After an intravitreal injection of TA, the posterior vitreous cortex was removed and the ILM peeled off. An attempt was made to aspirate all the TA crystals. No crystals were seen around the MH and at the bottom of the MH at the conclusion of the surgery and 20% sulphur hexafluoride gas (SF_6) was subsequently injected. The patient was told to maintain a facedown position for 3 days in accordance with the belief that 3 days of facedown positioning is sufficient to achieve MH closure (Krohn 2005).

The next day, TA crystals were seen in the MH. After the intravitreal gas had partially absorbed, OCT images showed a decrease in the fluid cuff and flattening of the MH, but retinal cysts were present (Fig. 1C, D). However, white TA crystals were detected in the MH, although the centre of the crystals had been absorbed. The MH reopened 2 weeks later when the intravitreal gas had been completely absorbed (Fig. 2A, B). After allowing time for the absorption of the TA

crystals, 20% SF_6 gas was injected intravitreally, at 3 weeks after the initial surgery. The MH was completely closed 1 week after the gas injection and vision recovered to 20/20 after 3 months.

These results suggest that an MH does not close completely and can reopen if TA crystals remain in it. Questions then arise about the mechanism leading to the reopening of the MH. Successful MH closure was achieved after the second gas injection using the same type of gas and the same duration of facedown positioning as in the initial procedure, but after resorption of residual TA in the MH. This may be attributable to a mechanical block by the TA crystals of the physiological interactions between the sensory retina and the retinal pigment epithelium (RPE). Alternatively, it may have been caused by the effect of TA as a corticosteroid because corticosteroids are known to alter the function of RPE cells (Yeung et al. 2003). A third possible reason might be that, because the patient was young, the vitrectomy was performed under general anaesthesia and therefore the patient was not moved to a facedown position for several hours. Triamcinolone acetonide crystals in the vitreous cavity must have settled in the MH while the subject was in the face-up position immediately after surgery.

Although this report concerns only one case, we suggest that the presence of TA crystals in an MH may prevent the complete closure of the MH. Therefore, careful and thorough aspiration of all TA crystals should be performed during surgery. Additional gas tamponade should be considered in such cases because it led to successful closure in our case.

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Surgical effects and complications of indocyanine green-assisted internal limiting membrane peeling for idiopathic macular hole

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ABSTRACT.

Purpose: **To compare the surgical outcomes and complications of vitrectomy with internal limiting membrane (ILM) peeling with or without indocyanine green (ICG) staining in eyes with an idiopathic macular hole.**

Methods: **This study involved a non-randomized, single-centre, retrospective, interventional case series. Rates of anatomical closure, visual acuities (VAs) and postoperative complications in 35 eyes of 31 patients who underwent ICG-assisted ILM peeling during macular hole surgery (stained group) were compared with those in 18 eyes of 16 patients who underwent the same procedure without ICG staining (non-stained group).**

Results: **Macular holes were closed following the initial surgery in 97% of the stained group and 94% of the non-stained group ($p > 0.999$). There was no significant difference in mean final VA between the stained and non-stained groups, but there was a lower percentage of eyes with postoperative vision > 20/25 in the stained group (15%) than in the non-stained group (44%) after 2 years ($p = 0.036$). Posterior retinal pigment epithelium atrophy, retinoschisis and visual field defects were observed only in the stained group.**

Conclusions: **The difference in mean final VA between the two groups was not significant. However, a lower percentage of eyes obtained VA ≥ 20/25 and a higher incidence of postoperative complications occurred in the stained group. These results indicate that some consideration should be made before ICG is used in macular hole surgery.**

Key words: complications – indocyanine green – internal limiting membrane – macular hole – vitreous surgery

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Introduction

Gass (1988) hypothesized that idiopathic macular holes resulted from tangential traction on the retina caused by the contraction of the prefoveal vitreous cortex. Based on this hypothesis, Kelly & Wendel (1991) reported good surgical results of pars plana vitrectomy (PPV) for macular hole, which had hitherto been untreatable. The procedures used in PPV for macular hole have improved since then in the effort to obtain better surgical outcomes. Several procedures have been tried, including adjuvant treatment, such as transforming growth factor-β (TGF-β) (Thompson et al. 1998), autologous serum (Liggett et al. 1995) and internal limiting membrane (ILM) peeling (Yooh et al. 1996; Park et al. 1999; Brooks 2000; Uemoto et al. 2002). The use of ILM peeling during macular hole surgery has resulted in higher rates of anatomical closure and greater improvements in visual acuity (VA).

To make the ILM more visible, a small amount of viscous material containing indocyanine green (ICG) is placed on the retinal surface around the macular hole. This makes the ILM more visible and easier to grasp and excise. This leads to better surgical outcomes because it reduces the

occurrence of mechanical damage to the sensory retina during the ILM peeling procedure (Kadonosono et al. 2000). However, rapid increase in the use of ICG during ILM peeling for macular hole surgeries (Da Mata et al. 2001; Kwok et al. 2001) has resulted in an increase in the number of cases with retinal damage to the retina and retinal pigment epithelium (RPE), which has been attributed to ICG toxicity because of postoperative changes (Engelbrecht et al. 2002). Ultrastructural findings in the retinal elements on the excised ILM support the toxic effect of ICG (Gandorfer et al. 2001). Previous experimental studies demonstrated that ICG was toxic to cultured human RPE cells (Sippy et al. 2001). Morphological and functional damage to the retina after exposure to ICG has also been observed in an animal model (Enaida et al. 2002) and in human donor eyes (Gandorfer et al. 2003).

The purpose of this study was to determine the efficacy of ICG-assisted ILM peeling for idiopathic macular hole. We retrospectively examined the medical records of cases with an idiopathic macular hole and compared the rates of anatomical closure, visual improvement, and intra- and postoperative complications following ILM peeling with ICG with those after ILM peeling without ICG.

Materials and Methods

The medical records for 91 eyes of 86 patients who underwent PPV combined with ILM peeling for idiopathic macular hole at Keio University Hospital between January 1999 and May 2002 were studied retrospectively (Fig. 1). All patients were fully informed about the treatment protocol and signed informed consent was obtained. The procedures used conformed to the tenets of the Declaration of Helsinki. Patients with cataracts that affected vision (Emery–Little classification > grade 3) and those with a follow-up period of < 1 year were excluded. All surgeries were performed by three of the authors (MI, SI and KS), all of whom had similar surgical experience in performing ILM peeling with and without ICG staining. Eyes in which surgery was performed by other surgeons were excluded.

All operated eyes were allocated to one of two groups: an ICG-stained group and a non-stained group. The stained group consisted of 35 eyes of 31 subjects who were operated on between July 2000 and May 2002. The non-stained group included 18 eyes of 16 patients operated on between January 1999 and June 2000, which did not have ICG staining during the surgery.

An operating microscope (Zeiss CS; Carl Zeiss Meditec, Tokyo, Japan) with co-axial illumination was used for the surgeries. The light from the microscope was usually turned off during the procedures on the posterior segment unless otherwise indicated. A fibre optic light source was used for endo-illumination (Accurus; Alcon Laboratories, Fort Worth, TX, USA, or Millenium; Bausch & Lomb, NY, USA), and the level and the distance of the light probe to the retina were kept constant throughout the operation. The surgical procedures included core vitrectomy. A posterior vitreous detachment was created by suction and a vitreous cutter.

A sample of 25 mg ICG (Daiichi Pharmacy Corp., Tokyo, Japan) was dissolved in 1 ml distilled water and further diluted with 4 ml balanced salt solution (BSS plus®; Alcon Laboratories). About 0.05 ml filtered ICG solution (0.5% solution, 5 mg/ml) was dropped on the retina after fluid –air exchange to avoid staining the posterior lens capsule. Immediately after the application, the ICG was rinsed out with infusion fluid and the residual dye was aspirated. The ILM then had a faint greenish appearance. An initial flap of ILM was created by microforceps. The visible ILM was then peeled off using microforceps for an area of 1–2 disc diameters around the macular hole using a technique similar to that of continuous curvilinear capsulorhexis for the anterior lens capsule. In the non-stained group, the transparent ILM was peeled off without ICG. At the end of surgery, the vitreous fluid was replaced with 20% sulphur hexafluoride (SF6) for a gas tamponade in both groups. The patients were instructed to lie face-down for 1 week after surgery.

The anatomical closure rate, visual improvement and intra- and postoperative complications were evaluated in each group. Visual acuity was measured at 1 and 2 years after surgery. Visual acuity measurements were

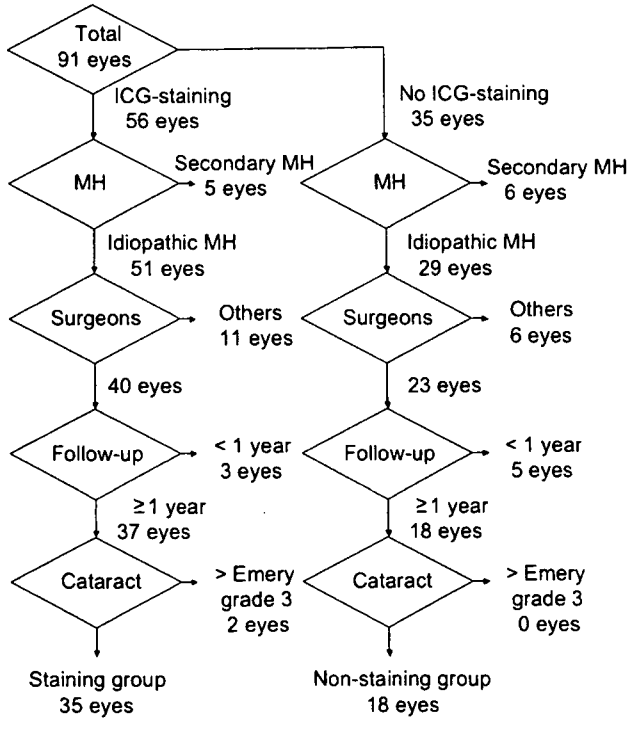

Fig. 1. Flowchart of all macular hole surgeries enrolled in the study. ICG = indocyanine green; MH = macular hole.

made by ophthalmologists or orthoptists using a Snellen chart. The visual fields were determined by Goldman perimetry in all patients pre- and postoperatively.

The numerical data were analysed using the unpaired *t*-test. The categorical variables were analysed using Fisher's exact probability test or chi-square test to compare the stages of macular hole.

Results

The mean age of patients in the stained group was 65.3 ± 6.6 years (mean ± standard deviation, range 54–79 years); that of patients in the non-stained group was 64.3 ± 7.5 years (range 55–75 years) (Table 1). The difference in mean age between groups was not significant ($p = 0.75$, unpaired *t*-test). Women accounted for 77% of patients in the stained group and 72% in the non-stained group; the difference in gender was not significant ($p > 0.999$, Fisher's exact probability test). The difference in the status of the lens was also not significant ($p = 0.65$, Fisher's exact probability test). Preoperative logMAR VA was 0.83 ± 0.27 in the stained group and 0.89 ± 0.23 in the non-stained group ($p = 0.28$, unpaired *t*-test). Preoperative VA was < 20/200 in 23 of 35 eyes in the stained group and in 12 of 18 eyes in the non-stained group ($p > 0.999$, Fisher's exact probability test).

The two groups did not significantly differ in terms of preoperative stage of macular hole according to the classification of Gass (1988) ($p = 0.73$, chi-square test). The duration of symptoms was 3.9 ± 3.8 months in the stained group and 4.7 ± 5.5 months in the non-stained group; this difference was not significant ($p = 0.53$, unpaired *t*-test). One eye in the non-stained group and five in the stained group were pseudophakic preoperatively; all eyes were pseudophakic postoperatively because lensectomy was performed in the phakic eyes simultaneously with macular hole surgery in 17 eyes in the non-stained group and 22 eyes in the stained group or postoperatively after cataract formation in eight eyes in the stained group. The average follow-up period was 28.1 months in the stained group and 35.1 months in the non-stained group.

Table 1. Characteristics of cases in both groups.

	Group		
	Stained	Non-stained	p-value
Number of eyes	35	18	
Patient age, mean (SD) (years)	65.3 (6.6)	64.3 (7.5)	0.75*
Gender (% female)	77	72	> 0.999†
Duration of symptoms, mean (SD) (months)	3.9 (3.8)	4.7 (5.5)	0.53*
Lens status, phakia (pseudophakia)	30 (5)	17 (1)	0.65†
Preoperative logMAR VA, mean (SD)	0.83 (0.27)	0.89 (0.23)	0.28*
Stage of macular hole			0.73‡
Stage II, *n* (%)	8 (23%)	4 (22%)	
Stage III, *n* (%)	18 (51%)	11 (61%)	
Stage IV, *n* (%)	9 (26%)	3 (17%)	
Observation period (months)	28.1 (8.6)	35.1 (9.2)	0.009*

* Significance calculated by unpaired *t*-test.
† Significance calculated by Fisher's exact probability test.
‡ Significance calculated by chi-square test.
VA = visual acuity; SD = standard deviation.

The rate of macular hole closure after the first surgery was 97% (34/35 eyes) in the stained group and 94% (17/18 eyes) in the non-stained group ($p > 0.999$, Fisher's exact probability test) (Table 2). The two eyes in which the macular hole was not closed underwent second surgeries, which resulted in closure. A larger area of the ILM was peeled in one eye in the stained

Table 2. Comparison of surgical results in both groups.

	Group		
	Stained	Non-stained	p-value
Initial anatomical closure rate	34/35 (97%)	17/18 (94%)	> 0.999†
Final closure rate	35/35 (100%)	18/18 (100%)	> 0.999†
Ratio of pseudophakia			
1 year	35 (100%)	18 (100%)	
2 years	35 (100%)	18 (100%)	
Preoperative logMAR VA, mean (SD)	0.83 (0.27)	0.89 (0.23)	0.28*
Postoperative logMAR VA, mean (SD)			
1 year	0.36 (0.25)	0.41 (0.30)	0.35*
2 years	0.33 (0.25)	0.37 (0.42)	0.29*
Postoperative VA ≥ 20/40			
1 year	18/35 (34%)	9/18 (50%)	> 0.999†
2 years	19/34 (56%)	9/16 (56%)	> 0.999†
Postoperative VA ≥ 20/25			
1 year	5/35 (14%)	7/18 (38%)	0.080†
2 years	5/34 (15%)	7/16 (44%)	0.036†
Postoperative complications (eyes)			
Anatomical complications	11	2	0.177†
Foveal RPE atrophy	4	2	
Retinoschisis	3	0	
Posterior RPE atrophy	2	0	
Retinal detachment	2	0	
Visual field defect	7	0	0.081†

* Significance calculated by unpaired *t*-test.
† Significance calculated by Fisher's exact probability test.
VA = best corrected visual acuity; RPE = retinal pigment epithelium.

group and in one eye in the non-stained group.

The mean preoperative VA (logMAR) was 0.83 ± 0.27 in the stained group and 0.89 ± 0.23 in the non-stained group ($p = 0.28$, unpaired *t*-test). Mean logMAR VA 1 year after surgery was 0.36 ± 0.25 in the stained group and 0.41 ± 0.30 in the non-stained group. After 2 years, the mean logMAR VA was 0.33 ± 0.25 in the stained group and 0.37 ± 0.42 in the non-stained group. Although the mean VAs in the stained group were slightly better, the differences were not statistically significant at either time ($p = 0.35$, $p = 0.29$, respectively; unpaired *t*-test) (Table 2). The percentage of eyes with postoperative VA > 20/25 was significantly greater in the non-stained than in the stained group; 38% versus 14% at 1 year and 44% versus 15% at 2 years ($p = 0.080$, $p = 0.036$, respectively; Fisher's exact probability test) (Table 2).

Postoperative complications were classified into anatomical and visual field defects. Anatomical complications were observed in 11 eyes in the stained group and two eyes in the non-stained group ($p = 0.177$, Fisher's exact probability test). Foveal RPE atrophy was detected in four eyes in the stained group and two eyes in the non-stained group. Vision in two of four eyes with foveal RPE atrophy in the stained group improved by > 3 Snellen lines, but that in the other two eyes and the two eyes in the non-stained group did not improve. Retinoschisis (three eyes), posterior RPE atrophy (two eyes) and retinal detachment by peripheral retinal breaks (two eyes) developed in only the stained group.

In one eye in the stained group that developed posterior RPE atrophy, whitish retinal oedema was seen in the inferior area within the vascular arcade on the first postoperative day. The macular hole was closed and the retinal oedema was replaced by pigmented RPE atrophy 2 weeks after surgery (Fig. 2A). Fluorescein angiography demonstrated a mottled pattern of hyperfluorescence in the atrophic area (Fig. 2B). The patient's vision improved to 20/50 from 20/200 preoperatively and Goldman perimetry showed a superonasal visual field defect corresponding to the atrophic area (Fig. 2C). Another case with similar findings was observed in the stained group.

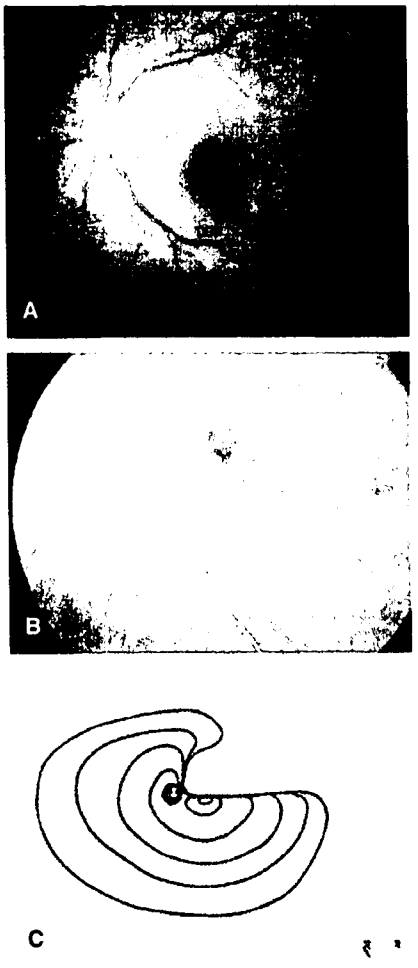

Fig. 2. Eye with posterior retinal pigment epithelium (RPE) atrophy. (A) Postoperative fundus photograph. Oval pigmented lesions are seen in the inferior macula, indicating RPE atrophy. (B) Early-phase fluorescein angiogram demonstrating the mottled pattern of hyperfluorescence in the pigmented area similar to that in phototoxicity. (C) Postoperative Goldmann visual fields, showing a superonasal visual field defect.

One patient in the stained group noticed an inferonasal visual field defect postoperatively soon after the absorption of the intraocular gas in an eye that developed retinoschisis. Two months after surgery, a tractional retinal detachment with epiretinal fibrosis developed in the superotemporal region of the macula of the right eye (Fig. 3A), corresponding to the area of the visual field defect (Goldmann perimetry) (Fig. 3B). Optical coherence tomography (OCT) showed a retinal detachment together with retinoschisis (Fig. 3C). The epiretinal membrane was excised and vision improved to 20/20, although the retinoschisis and the inferonasal visual field remained unchanged. The retina was attached after the surgery (Fig. 3D).

Electron microscopic analysis of the dissected membrane during the second operation showed flattened fibrous astrocytes attached to the extracellular matrix consisting of fibrous components and ILM. At high magnification, deposits of cellular debris were noticed on the retinal side of the ILM, possibly representative of glial cell processes; retinal elements such as Müller cell membranes and retinal debris were not found (Fig. 3E, F). The patient developed a macular hole in the fellow eye in January 2003, which was successfully treated by PPV combined with ILM peeling without ICG. Her vision improved from 20/50 to 20/20 without any retinoschisis or visual field impairment.

Postoperative visual field defects were detected only in the stained group, but the number of eyes was not significantly greater ($p = 0.081$, Fisher's exact probability test). Two eyes in the stained group had glaucoma preoperatively and the visual field did not change after the surgery. None of the other eyes had visual field defects preoperatively. The cases with visual field defects postoperatively included three eyes with retinoschisis, two eyes with posterior RPE atrophy, one eye with an inferotemporal visual field defect, and one eye with a centripetal visual field.

Discussion

Inner limiting membrane peeling was easier to perform in the stained group than in the non-stained group, and no intraoperative complications were noted following the use of ICG. However, 97% of eyes in the stained group and 94% of eyes in the non-stained group achieved anatomical closure ($p > 0.999$). Postoperative VA did not differ significantly in the two groups at either postoperative years 1 or 2 ($p = 0.35$, $p = 0.29$, respectively). In addition, the percentage of eyes

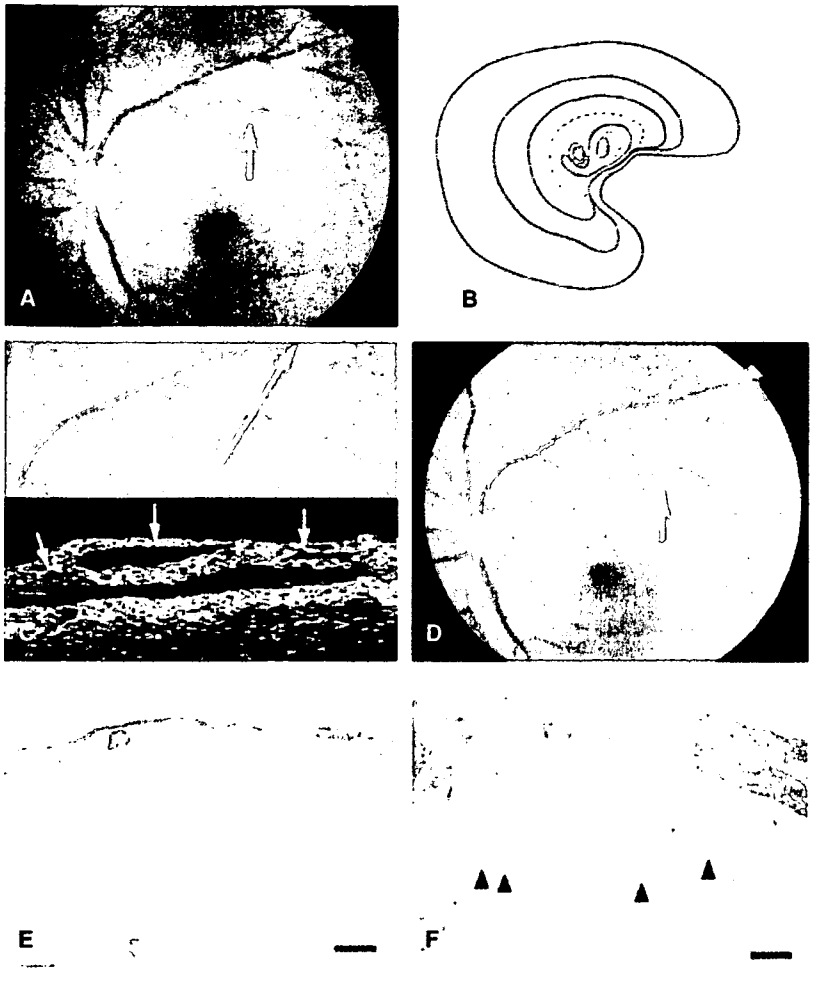

Fig. 3. Eye with retinoschisis. (A) Postoperative fundus photograph showing the closed macular hole and tractional retinal detachment associated with an epiretinal membrane (arrow), which developed beyond the edge of the peeled internal limiting membrane (ILM). (B) Postoperative Goldmann visual fields showing an inferonasal visual field defect corresponding to the tractional detachment. (C) Postoperative optical coherence tomogram showing intraretinal dehiscence (white arrows). (D) Postoperative fundus photograph after removal of the epiretinal membrane, showing disappearance of tractional detachment (arrow). (E) Low magnification electron photomicrograph of an excised dissected epiretinal membrane (bar: 4 μm). The epiretinal membrane consists of flattened astrocytes with the ILM. (F) High magnification electron photomicrograph of an excised epiretinal membrane showing dense deposits of cellular elements (arrowheads, bar: 2 μm).

with postoperative VA > 20/25 was not significantly different in the two groups except at 2 years ($p = 0.036$) because of the loss to follow-up between years 1 and 2 of two patients with VA < 20/25 in the non-stained group. However, postoperative complications were more frequent in the stained group.

Among the anatomical complications, posterior RPE atrophy and retinoschisis were found only in the stained group, but foveal RPE atrophy was seen in both groups. Posterior RPE atrophy was detected in two cases, and the mottling pattern in the fluorescein angiograms were similar to that reported as typical of phototoxicity (Michels et al. 1992; Van den Biesen et al. 2000). Thus, the posterior RPE atrophy was most probably caused by phototoxicity. We were unable to eliminate the phototoxic effect of the surgical microscope, as posterior RPE atrophy was seen on the side opposite to the light pipe and was also seen in eyes that did not have cataract surgery. The inferotemporal visual field defects after the surgery in the stained group were probably caused by fluid–air exchange, as has been described previously (Kerrison et al. 1997), but the centripetal visual field defects following the use of ICG have been reported as an adverse effect of ICG (Kanda et al. 2004).

Indocyanine green is a water-soluble tricarbocyanine dye with a strong absorption band at 600–900 nm. It is clinically approved to determine liver function, cardiac output and blood volume (Fox et al. 1957). In the ophthalmological field, ICG angiography is commonly used to assess choroidal circulation. However, ICG has a photothermal effect and radiates heat after the absorption of light (Fox et al. 1957). This property is clinically used in photodynamic therapy with a local exposure of an 805-nm diode laser after intravenous injection of ICG for colonic cancer (Baumler et al. 1999), mucosal lesion in the stomach (Yamashita et al. 1999) and AIDS-associated Kaposi's sarcoma (Abels et al. 1998). However, photocoagulation with the 805-nm infrared diode laser following ICG produces more intense and superficial burns (Blem et al. 2002). Indocyanine green absorbs the longer wavelengths of infrared, but peaks in absorbance at the wavelength emitted by the endoillumination light source (Fox & Wood 1960; Van den Biesen et al. 2000).

Two light sources were used in this study, the Accurus system (halogen light, wavelength 380–700 nm; Alcon) and the Millenium system (metal halide, 380–850 nm; Bausch & Lomb). The Millenium system was used in the two cases of RPE atrophy. Indocyanine green has a maximal absorption at 800 nm, which is within the wavelength of absorption of the metal halide light source. This might be the reason for the posterior RPE atrophy in both cases. The photodynamic effect of ICG following endoillumination might cause thermal injury and enhance phototoxic damage to the retina. Care should be taken in vitreous surgery with ICG application under metal halide endoillumination.

Ultrastructural studies have shown that the cellular elements in ILM specimens removed after ICG-assisted ILM peeling resembled the plasma membrane of Müller cells and other undetermined retinal structures adherent to the retinal side of the ILM

(Gandorfer et al. 2001). However, histological findings disclosed no difference between patients with or without visual field defects after the use of ICG (Gandorfer et al. 2001). Our ultrastructural findings in the excised membrane in the stained group also showed no retinal damage but did reveal preretinal fibrosis at the edge of the peeled ILM. The visual field defects extended to the periphery from the corresponding area and did not improve after reattachment of the retina by subsequent vitreous surgery. This indicated that the retinal damage was caused by retinoschisis. The retinoschisis might have been caused by contraction of an epiretinal membrane on the disorganized inner retina or by intraoperative mechanical damage. However, the patient noticed a visual field defect in the ICG-treated eye when the intraocular gas bubble disappeared, although no visual field defect was seen in the other eye, which underwent vitrectomy and ILM peeling without ICG. Exposure of the ICG-stained ILM to wavelengths of 620–760 nm has been reported to result in severe damage to the inner retina, including loss of ILM, cellular disorganization and fragmentation of the interface in human donor eyes (Gandorfer et al. 2003).

The use of ICG has been reported to be effective in improving the visibility of the ILM and facilitating the complete excision of perifoveolar tissue (Kadonosono et al. 2000). As a result of the improved visibility of the ILM, surgical time may be shortened and the potential for light toxicity may also be reduced. Nevertheless, we found a higher incidence of anatomical complications in the stained group, suggesting possible adverse effects of ICG. The enhanced visibility of the ILM by ICG might have allowed the peeling of a larger area of the ILM, which may cause mechanical damage to the retina.

The toxicity of ICG on RPE cells was shown to be dose-dependent and illumination-dependent in an *in vitro* study (Yam et al. 2003). However, Jackson et al. (2004) showed that the preparations of ICG most commonly used clinically did not result in significant damage to cultured RPE cells in the presence of illumination from a xenon light source, although they found relatively small changes in lower osmolarities and higher concentrations. Hyperconfluent ARPE19 cells have been reported to be more resistant to isotonic ICG (1 mg/ml) than previously described for immature ARPE19 cells, even after prolonged exposure (Kiilgaard et al. 2006). Thus, RPE cells may be rather resistant to ICG toxicity, by contrast with ganglion cells. The apoptosis-related pathways have been shown to cause the cell death of cultured glial cells initiated by ICG (Murata et al. 2005).

We used a concentration of ICG of 5 mg/ml (0.5%) under air over the macula according to the initial report by Da Mata et al. (2001); however, our ICG was immediately washed out, which makes our process differ from that of Da Mata et al. (2001). This concentration was higher than that used in recent reports. Instillation of ICG after fluid–gas exchange has also been described and a minimal effective concentration of about 1 mg/ml (0.1%) reported (Kwok et al. 2003). Brazitikos et al. (2004) reported a case in which vision improved to 20/30, even after massive subretinal diffusion of ICG. However, even a brief exposure of cultured human RPE cells to ICG resulted in a decrease in the mitochondrial enzyme activity without histological changes (Sippy et al. 2001). Although residual ICG was not observed ophthalmoscopically during postoperative follow-up examinations, infrared scanning laser ophthalmoscopy showed that ICG can remain on the retinal surface and foveal RPE for 6 weeks after surgery (Weinberger et al. 2001).

The incidence of postoperative visual field defects has also been described as ICG dose-dependent in a clinical study (Kanda et al. 2004). The use of lower concentrations of ICG in irrigating fluid has been described as preventing ICG-related complications (Ando et al. 2004). Because our study examined a small number of cases and was not a randomized, multicentre study, further studies are needed to clarify this issue.

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Patients' Descriptions of Visual Sensations During Pars Plana Vitrectomy under Retrobulbar Anesthesia

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• PURPOSE: To investigate the visual sensations experienced by patients during vitrectomy under retrobulbar anesthesia.

• DESIGN: Cross-sectional study.

• METHODS: Fifty-six men and 45 women with a mean age of 62.2 ± 11.9 years (range, 30 to 89 years) were studied. Twenty-two eyes had an idiopathic epiretinal membrane, 10 had an idiopathic macular hole, 29 had macular edema (16 resulting from diabetic retinopathy and 13 resulting from retinal vein occlusion), 14 had proliferative diabetic retinopathy, 13 had rhegmatogenous retinal detachment, four had proliferative vitreoretinopathy, and nine had other retinal diseases. The patients were questioned about their visual sensations during and within three hours after vitrectomy, which was performed under retrobulbar anesthesia using 2% lidocaine hydrochloride. Visual sensations perceived by the patients during surgery were reviewed.

• RESULTS: Ninety-one of the 101 patients experienced some type of visual sensation during the vitrectomy. Ninety-one (90.1%) patients reported seeing lights, 73 (72.3%) patients reported seeing one or more colors, and 57 (56.4%) patients reported seeing movements or moving objects. Of these latter 57 patients, 54 saw instruments and nine (8.9%) saw the surgeon's fingers or hands. In the 94 cases that had triamcinolone-assisted vitrectomy, 35 (37.2%) reported seeing many diffuse whirling black spots. Six patients (5.9%) found the visual experiences frightening.

• CONCLUSIONS: Visual sensations are experienced by approximately 90% of the patients despite full pain control, and surgeons should warn patients of these possibilities because they can be frightening. This should minimize patients' anxiety and stress during the surgery. (Am J Ophthalmol 2007;144:245–251. © 2007 by Elsevier Inc. All rights reserved.)

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VISUAL SENSATIONS EXPERIENCED BY PATIENTS DURING cataract surgery have been well documented.[1–9] More than 80% of the patients undergoing cataract surgery reported a wide variety of visual sensations, including flashing white or colored lights, or both; movements; instruments; and the surgeon's fingers or hands. However, little information is available on the visual sensations experienced during vitrectomy.[10–12] Recently, one of the authors (M.I.) performed vitrectomy on a graphic artist, and he not only described but also drew detailed pictures of his visual experiences during vitrectomy.[13] The drawings corresponded very well with the intraocular manipulations during the different phases of vitrectomy. This prompted us to investigate in more detail the visual sensations of patients who underwent pars plana vitrectomy for different vitreoretinal pathologic characteristics.

METHODS

ONE HUNDRED AND ONE PATIENTS WITH VITREORETINAL pathologic features who underwent pars plana vitrectomy between February 2005 and December 2005 were studied. The patients were interviewed during and within three hours after the vitrectomy regarding their visual experiences during the surgery. All patients were undergoing vitrectomy for the first time, and all surgeries were performed by some of the authors (M.I., K.Sh., S.I., Y.I., Y.O., H.S., K.Su.) under retrobulbar anesthesia by 5.3 ± 2.5 ml 2% lidocaine hydrochloride (AstraZeneca Pharma, Bangalore, India). The patients were also premedicated with 2 mg diazepam, a benzodiazepine, unless there was a contraindication for its use.

An operating microscope (Zeiss CS; Carl Zeiss, Meditec, Tokyo, Japan) with coaxial illumination was used for the surgeries. The light from the microscope usually was turned off during the procedures on the posterior segment unless otherwise indicated. A fiber optic light source was used for endoillumination, and the level was kept constant throughout the operation. Special care was paid to keeping the intraocular pressure constant by controlling either the height (40 cm from eye surface) of the bottles for intraocular irrigation (BSS plus®; Alcon Laboratories Inc, Fort Worth, Texas, USA) or the intraocular pressure (30 mm Hg).

The surgical procedures were approximately the same for all eyes and consisted of the creation of sclerotomies for

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TABLE 1. Questions Asked of Patients during and within Three Hours after Vitreous Surgery

1. Do you see anything?
2. Do you see light?
3. If yes, describe its color, shape, and extension.
4. Do you see any objects?
5. If yes, what does it look like?
6. Did you feel pain? Please rate the fear you felt on following scale: 0 = no pain, 1 = weak pain, 2 = moderate pain, 3 = terrible pain.
7. Did you feel that your visual experience was frightening?
8. Considering your visual experience, now which do you think is better: to have the same operation under local anesthesia or general?

three ports; core vitrectomy with the vitreous cutter under endoillumination; intravitreal injection of triamcinolone acetonide (TA); removal of the epiretinal membrane, internal limited membrane, or both; fluid–air exchange; and endolaser photocoagulation. Phacoemulsification and intraocular lens implantation were performed before the vitrectomy in 51 eyes, and the intraoperative questioning was carried out mainly when procedures were being performed on the posterior segment.

Very similar questions were asked to each patient during each procedure (Table 1). These questions were selected to provide information regarding the visual sensations experienced during different phases of the 30 minutes of surgery and the three hours after surgery. Patients also were asked to rate their pain during surgery as 0 = no pain, 1 = slight pain, 2 = moderate pain, and 3 = severe pain. The dialogue with the patient was almost continuous during the different phases of vitrectomy, and continuous reassurances were given that everything was proceeding nicely. The patient's description, preoperative visual acuity, and vitreoretinal disease were reviewed.

The Chi-square test was used to test for independence, and the Fisher exact probability test was performed to determine the correlation of each clinical factor to each visual sensation. To minimize type I error, the statistical significance was set at .01 (.05/5) according to the Bonferroni test. The influence of each procedure on the frequency of visual sensations was investigated statistically using an m × n contingency table. The statistical comparison of preoperative visual acuity and postoperative visual acuity between patients with and without each visual sensation such as light, color, or moving objects during surgery was carried out using the Mann–Whitney *U* test. The statistical significance was set at $P = .05$.

RESULTS

THE DEMOGRAPHICS OF THE PATIENTS ARE SHOWN IN Table 2, and the visual sensations reported for each type of

TABLE 2. Demographics of the Patients with Each Vitreoretinal Pathologic Feature Who Reported Experiencing Visual Sensations During Pars Plana Vitrectomy under Retrobulbar Anesthesia

	Disease (No. Eyes)						
	MH (10)	ERM (22)	ME (29)	PDR (14)	RRD (13)	PVR (4)	Other (9)
Mean age ± standard deviation (range), years	68.1 ± 11.6 (53–89)	65.8 ± 7.6 (55–80)	62.7 ± 10.9 (30–77)	53.0 ± 10.3 (31–68)	62.0 ± 9.6 (46–78)	52.3 ± 17.6 (30–73)	64.6 ± 18.0 (38–85)
Gender (male:female)	2:8	8:14	15:14	9:5	11:2	3:1	8:1
Preoperative visual acuity,* range (median)	0.15–0.7 (0.2)	0.1–1.0 (0.4)	0.06–0.7 (0.2)	HM–0.6 (0.02)	HM–0.8 (0.02)	HM–0.07 (0.0009)	LP(+)–0.5 (0.003)

ERM = epiretinal membrane; HM = hand movements; LP = light perception; MA = macroaneurysm; ME = macular edema; MH = macular hole; PDR = proliferative diabetic retinopathy; PVR = proliferative vitreoretinopathy; RRD = rhegmatogenous retinal detachment.

*Visual acuity of counting fingers and hand movements was converted to 0.001 and 0.0001, respectively, when the median was calculated according to the previous report (Holladay JT. Visual acuity measurements. J Cataract Refract Surg 2004;30:287–290).

TABLE 3. Frequency of the Various Visual Sensations Experienced by Patients with each Vitreoretinal Pathologies During Pars Plana Vitrectomy under Retrobulbar Anesthesia

	Disease (No. Eyes)						
	MH (10)	ERM (22)	ME (29)	PDR (14)	RRD (13)	PVR (4)	Other (9)
Light	10 (100)	22 (100)	26 (89.7)	12 (85.7)	11 (84.6)	3 (75)	7 (77.8)
Color	9 (90)	18 (81.8)	18 (62.1)	9 (64.3)	11 (84.6)	1 (25)	7 (77.8)
Moving object							
Instrument	8 (80)	12 (54.5)	17 (58.6)	9 (64.3)	4 (30.8)	0 (0)	4 (44.4)
TA particles	7 (70)	4/17 (23.5)*	13 (44.8)	6 (42.9)	2 (15.4)	0 (0)	2/7 (28.6)*
Vitreous	0 (0)	0 (0)	4 (13.8)	4 (28.6)	0 (0)	0 (0)	0 (0)
Membranes	3 (30)	6 (27.3)	4/25 (16.0)*	0/10 (0)*	0/9 (0)*	0 (0)	1/3 (33.3)*
Other†	3 (30)	3 (13.6)	3 (10.3)	2 (14.3)	1 (7.7)	0 (0)	0 (0)
Fear	0 (0)	2 (9.1)	2 (6.9)	1 (7.1)	0 (0)	1 (25)	0 (0)

ERM = epiretinal membrane; ME = macular edema; MH = macular hole; PDR = proliferative diabetic retinopathy; PVR = proliferative vitreoretinopathy; RRD = rhegmatogenous retinal detachment; TA = triamcinolone acetonide.

*Data are shown as number of eyes (%) except in values indicated by asterisks, where the procedure was performed only in selected eyes (the denominator shows the number of eyes).

†Asteroid hyalosis, n = 1; vitreomacular traction syndrome, n = 1; intraocular lens dislocation, n = 1; multifocal posterior pigment epitheliopathy, n = 1; central retinal artery occlusion, n = 1; vitreous hemorrhage of unknown origin, n = 3; macroaneurysm, n = 1.

TABLE 4. The Relationship between the Various Clinical Findings and the Frequency of the Various Visual Sensations Experienced by Patients During Pars Plana Vitrectomy under Retrobulbar Anesthesia

	Amount of Anesthesia			Gender			Age			Pain Score*		
	3 ml or Less (n = 28)	More than 3 ml (n = 73)	P value	Male (n = 56)	Female (n = 45)	P value	40 yrs or Younger (n = 6)	Older than 40 yrs (n = 95)	P value	0 or 1 (n = 78)	2 or 3 (n = 12)	P value
Light	24 (85.7)	67 (91.8)	.4577†	48 (85.7)	43 (95.6)	.1783†	6 (100)	85 (89.5)	>.9999†	69 (88.5)	11 (91.7)	>.9999†
Color	22 (78.6)	51 (69.9)	.5291	35 (62.5)	38 (84.4)	.0259	4 (66.7)	69 (72.6)	.6681†	56 (71.8)	9 (75.0)	>.9999
Moving object												
Instrument	12 (42.9)	42 (57.5)	.27	28 (50.0)	26 (57.8)	.5618	5 (83.3)	49 (51.6)	.2115	42 (53.8)	4 (33.3)	.311
Others‡	10 (35.7)	38 (52.1)	.2107	22 (39.3)	26 (57.8)	.0987	4 (66.7)	44 (46.3)	.4197†	37 (47.4)	4 (33.3)	.5473
Fear	0 (0)	6 (8.2)	.1829†	2 (3.6)	4 (8.9)	.4027†	1 (16.7)	5 (5.3)	.3142†	5 (6.4)	1 (8.3)	.5875†

Data are shown as number of eyes (%). To minimize type I error, statistical significance was considered when $P < .01$ according to the Bonferroni test.

*Pain score was obtained from 90 patients: 0 = no pain; 1 = weak pain; 2 = moderate pain; 3 = terrible pain.

†The Fisher exact probability test was performed to investigate the correlation of each clinical factor to each visual sensation except these two issues, which were investigated statistically using the Chi-square test for independence.

‡Triamcinolone acetonide particles, vitreous, or membranes.

vitreoretinal disease are listed in Table 3. There were no obvious differences in the incidence of the type of sensation for the different vitreoretinal pathologic features. Pain scores were obtained from 90 patients; 62 patients rated the pain as 0, 17 patients rated the pain as 1, nine patients rated the pain as 2, and two patients rated the pain as 3. Of the 44 patients experiencing some degree of pain, two patients (4.5%) did not report experiencing any visual sensations, whereas among the 46 patients who rated the pain as 0, nine patients (19.6%) did not report experiencing any visual sensations. No significant correlation was found between the number of the patients with no visual sensations and the pain score.

Ninety-one (90.1%) patients reported seeing lights, 73 (72.3%) reported seeing one or more colors, and 57 (56.4%) reported seeing movements or moving objects. Of these latter patients, 54 (94.7%) reported seeing surgical instruments, and nine (8.9%) saw the surgeon's fingers or hands.

In the 94 cases that had TA-assisted vitrectomy, 34 (36.2%) patients reported that they saw multiple diffuse whirling black spots, whereas the other 49 pa-

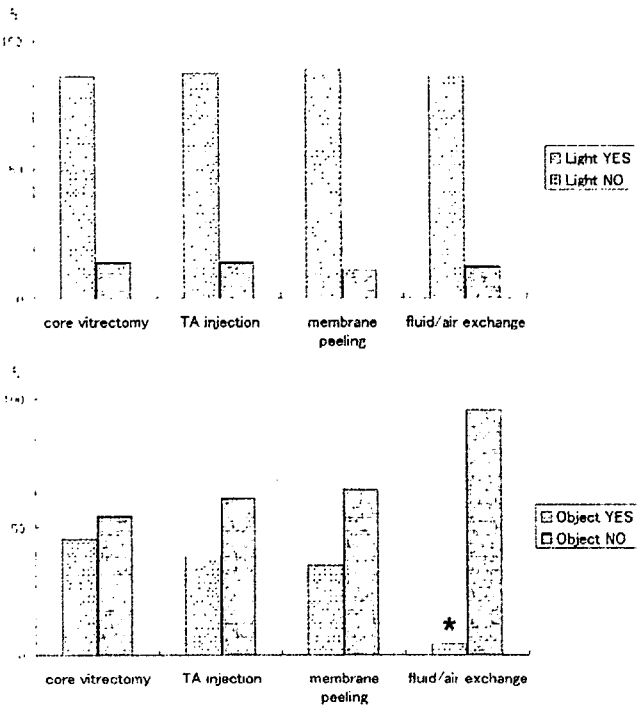

FIGURE 1. Bar graphs demonstrating the frequency of patients who experienced visual sensations during each procedure of pars plana vitrectomy performed under retrobulbar anesthesia. (Top) Frequency of patients who experienced a light sensation. There was no significant correlation between the number of patients experiencing light sensations and the surgical procedure. (Bottom) Frequency of the patients who experienced a moving object during each procedure. The frequency of seeing some object was significantly lower during the fluid–air exchange (asterisk; $P < .0001$). TA = triamcinolone acetonide.

tients saw only lights and color. The colors seen included white (25 patients; 24.8%), blue (17 patients; 16.8%), green (two patients; 2.0%), yellow (18 patients; 17.8%), orange (13 patients; 12.9%), and red (12 patients; 11.9%). Six patients (5.9%) found the visual experience frightening.

The relationship between the specific visual sensation and the clinical findings is shown in Table 4. The amount of anesthesia, gender, age, and pain did not seem to affect the number of patients reporting the various visual sensations (Table 4). The patients who reported lower pain levels tended to experience moving objects more frequently, but the correlation was not significant. The six patients who reported the visual experience to be frightening did not have any special distribution concerning age or gender, although they did have lower amounts of anesthesia. Interestingly, the pain score also was lower in these six patients.

The reported visual sensation perceived during each procedure is shown in Figure 1. In a representative case, the patient saw colorless swirling fluid during the early phase of vitrectomy, which probably corresponded to the intraocular irrigation used during core vitrectomy. Later, he reported seeing numerous swirling, black and gray spots resembling snowflakes when the white TA crystals were injected into the vitreous. Twenty-seven patients described a sharply tapered shadow that moved into the center of the field just before the membrane-like material was peeled off. Interestingly, some of the patients reported perceiving hemorrhages as red. One patient reported that the instrument in the vitreous cavity was silver, and one other patient described it as gold. Patients with vitreous hemorrhage often said that brown or red swirling gel was seen during core vitrectomy.

The relationships between visual sensations, such as light, color, and moving objects, and visual acuity before or after surgery are shown in Figure 2. There was a tendency for patients who experienced mild visual sensations to have lower preoperative visual acuity. Also, patients with better intraoperative visual sensations had better postoperative visual acuities.

Additionally, the following comments were obtained spontaneously during interviews carried out at the bedside after the surgery: eight patients commented that the visual experience during surgery was very good in that it allowed the patient feel that he or she was actually undergoing treatment; six patients commented that the surgeon's remarks to the patient and the dialogue between the surgeon and assistant suggest that the surgery was going well were very good in that they provided the patient with peace of mind; and five patients commented that the visual experience during surgery was very interesting in that it allowed the patient to be calm and composed.

DISCUSSION

OUR RESULTS DEMONSTRATE THAT PATIENTS EXPERIenced a variety of visual sensations during vitreous surgery under retrobulbar anesthesia, even though the anesthesia and analgesia were deep enough to perform the surgical procedures with minimal pain. Only 10 (9.9%) of the patients reported a total loss of light sensation, indicating that neural conduction along the optic nerve was completely blocked. This is in good agreement with previous reports on the effectiveness of retrobulbar anesthesia (Table 5).[1,3,7–9,14–16]

Intravitreal instruments were perceived in 53.5% of our patients. We previously reported on a patient who not only described but also drew what he saw during vitrectomy with great accuracy.[13] These drawings illustrated how well the visual perception of the patient corresponded with the surgical procedure being performed even when the procedure is not focused on the retina through the optical system of the eye.

Our results indicate that the type of visual sensation was not correlated with the type of vitreoretinal diseases. But eyes with poor macular function, such those with rhegmat-