• Clinical Research •

Endoscopy-assisted vitrectomy for severe ocular penetrating trauma with corneal opacity

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Abstract

● **AIM:** To assess the utility and efficiency of endoscopy-assisted vitrectomy (EAV) for the treatment of corneal opacity in severe ocular trauma.

● **METHODS:** Patients who underwent fundus examination using a preoperative slit lamp and intraoperative endoscopy, followed by EAV and additional surgery were retrospectively recruited. Silicone oil removal and penetrating keratoplasty were used in selected eyes at postoperative follow-ups. Outcome measurements included the best corrected visual acuity (BCVA), intraocular pressure (IOP), findings of endoscopic fundus examination, and postoperative complications.

● **RESULTS:** Twenty-one eyes with severe ocular trauma and corneal opacity were followed up for 24–36mo. Retinal detachment (RD) and vitreous haemorrhage (VH) were identified in 16 eyes (76.2%), RD only in four eyes (19.0%), and VH combined with intraocular foreign body in one eye (4.8%). All eyes underwent at least three surgeries. Stage-I surgeries involved wound closure (100%), lens extraction (76.2%), and anterior vitrectomy (14.3%). Stage-II surgeries involved scleral buckling (28.6%), membrane peeling (47.6%), retinal laser photocoagulation (100%) and silicone oil tamponade (100%) using EAV. Stage-III surgeries were conducted using endoscopy including silicone oil removal (52.4%), retinal laser photocoagulation (52.4%) and penetrating keratoplasty (28.6%). Nearly all eyes showed improvements in BCVA and IOP. Although there were no severe complications, glaucoma was noted in one eye, chronic hypotony in another eye, and band keratopathy in three eyes.

● **CONCLUSION:** EAV is an effective adjunct for restoring ocular anatomical structures and visual function in the case of corneal opacity after severe ocular trauma.

● **KEYWORDS:** corneal opacity; endoscopy-assisted vitrectomy; penetrating keratoplasty; severe ocular trauma; retinal detachment

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INTRODUCTION

Ocular trauma is an important cause of vision loss. Severe ocular penetrating trauma often disrupts the integrity of the eye and may be accompanied by severe retinal detachment (RD), choroidal detachment, vitreous haemorrhage (VH), presence of intraocular foreign bodies (IOFBs), or proliferative vitreoretinopathy (PVR)[1-3]. Breakdown of the blood-retina barrier can lead to cellular proliferation and the production of extracellular matrix on the retinal and subretinal surfaces as well as the occurrence of epiretinal and subretinal membranes, circumferential peripheral membrane traction, and retinal folds[4-6]. These injuries can lead to corneal opacity due to irregular corneal wounds, scarring or small pupils due to inhibition of dilation from the fibrinous exudation, hyphaemia, and blood-stained cornea. Therefore, it is challenging to perform traditional pars plana vitrectomy or other vitreoretinal surgeries using a traditional microscope, particularly when membrane removal or retinectomy in the peripheral retina zone is required.

Although endoscopy-assisted ophthalmological surgery is a relatively established technique, it is not used extensively. The current intraocular endoscopes project the intraocular images, which are captured using a lens on the distal tip, onto an electronic monitor, and each endoscope has an optical duct illuminating system[7]. Various gradient index lens systems are used, with 19-gauge, 20-gauge, or 23-gauge endoscope. As the endoscope's size determines the imaging resolution and the field of view (FOV), with 19-gauge endoscope having 17 000 pixels and 140° FOV, the 20-gauge endoscopes having 10 000 pixels and 110° FOV, and the 23-gauge endoscopes having 6000 pixels and 90° FOV[8]. Hence, endoscopes must cross the anterior segment to capture images using their distal tip and can provide a high magnification with panoramic, unobstructed, and undistorted views of the retina, especially when the media is opaque, and the space is not accessible between the vitreous base and anterior segments behind the iris[9-10]. Traditional microscopes provide a top-down perspective from outside the patient's clear anterior media, while endoscopes provide a unique intraoperative view from inside the vitreous cavity (*i.e.,* the side-on perspective)[7-8]. Recent technological advances, including the development of a wide-angle viewing system, have increased the indications for microincision vitrectomy in complicated cases; however, it remains difficult to perform vitrectomy with a transpupillary view in the case of media opacities. Then, we observed several cases of chronic hypotony which were intractable to deal with, and we found that endoscope was proved to be an effective and useful tool to observe the anterior vitreous segment and operate the intraocular surgeries[9]. By endoscopy-assisted vitrectomy (EAV), it is easily accessible to observe the state of the ciliary process and the ciliary body directly; besides the surgical strategies and methods of those cases of chronic hypotony could become much easier and more specific, which would benefit the patients. EAV makes it possible to perform vitrectomy and allows observation of any part of the retina, even when encountered with corneal opacity or other opaque media[8,11]. So, the present case series further more details the applications of EAV for corneal opacity after severe ocular trauma and the surgical outcomes of these patients.

PARTICIPANTS AND METHODS

Ethical Approval This study was performed in accordance with the principles of the Declaration of Helsinki and complied with the Healthy Insurance Portability and Accountability Act of 1996, and we obtained Institutional Review Board (IRB) approval with the approval number is NZLLKZ2022190. Informed consent was obtained verbally from all participants before EAV.

Participants We retrospectively recruited 21 patients who underwent EAV for severe ocular trauma with severe corneal opacity combined with RD and/or VH performed by one vitreoretinal surgeon (Zou YP) at the Department of Ophthalmology, General Hospital of Southern Theater Command of PLA between January 2014 and June 2019. The patients were followed up for 24–36mo. The exclusion criteria were penetrating ocular trauma of the cornea, sclera up to 4 mm posterior to the limbus, cornea laceration less than 5 mm in the para-corneal and peripheral-corneal zones, and ocular blunt injury.

Surgical Technique All eyes underwent surgery at least thrice. Stage-I surgeries involved wound closure, and primarily included corneal scleral fissure sutures with irregular corneal and/or scleral wounds. Further, lens extraction and anterior vitrectomy were performed when cataract or severe lens luxation occurred. The anterior chamber was cleared in patients with hyphaemia when required. Stage-II surgeries (EAV and other methods) involved repairment of the ocular structure and function. EAV was performed using an endoscopy system (PolyDiagnost, Pfaffenhofen, Germany) with a 20-gauge trocar-cannula system. Corneal limbal-tunnel incisions were made at the 9 o'clock to 12 o'clock meridian, if required. The vitreous and lens were extracted, retinal laser photocoagulation applied, and silicone oil tamponade performed to achieve reattachment of the retina. Heavy silicone oil could be chosen according to the specific situation, and Desiron 68 of 2000 cS was used in some cases. To release proliferative membrane traction, retinal membrane peeling (MP) using perfluorocarbon liquid (PFCL) and scleral buckling were performed in eyes with severe proliferation, such as a thick and stiff proliferating membrane and stiff retina. Scleral buckling was applicable to retinal tears located in the inferior retina. Stage-III surgeries were conducted using endoscopy for fundus examination to evaluate the status of the retina and determine indications for further surgeries. Silicone oil removal was conducted when the retina was flat without proliferative membrane and retina traction. In these cases, we usually evaluated the fundus' state and the possible best corrected visual acuity (BCVA), if the visual acuity improved much more obviously, then intraocular lens (IOL) fixation or a combination with penetrating keratoplasty was considered. Of course, these surgeries were not only selected according to the severity of maculopathy, but also the patients' requirements. Meanwhile, silicone oil exchange was recommended in other cases of silicone oil emulsification, and silicone oil tamponade was applied in other eyes. The time interval between Stage-I and Stage-II operations in these eyes was almost 1–2wk. The time interval between Stage-II and Stage-III operations was approximately 12mo.

Parameters of Follow-up We reviewed chart data of all patients to collect data on ocular pathology, time interval between three surgeries, BCVA, intraocular pressure (IOP), and complications at preoperative and postoperative visits. The time interval between each postoperative visit was 3mo. BCVA was recorded at each postoperative visit using a standard projected Snellen chart and then transferred into logarithmic minimum angle of resolution (logMAR) for data analysis. Light perception (LP) was recorded as logMAR 4, hand motion (HM) was recorded as logMAR 3, counting fingers (CF) 10, 20, 30, and 40 cm were recorded as logMAR 2.7, logMAR 2.4, logMAR 2.2, and logMAR 2.1 respectively. All preoperative and postoperative IOP measurements were made using a Goldman slit-lamp-mounted tonometer (Haag-Streit International, Bern, Switzerland), or Icare tonometer (Icare Finland OY, Finland) with severe cornea scars or irregular astigmatism. Ultrasonic biological microscopy, B-ultrasonography, or computed tomography (CT) was performed preoperatively and postoperatively when necessary.

Statistical Analysis Statistical analyses were performed used SPSS software version 27.0 (SPSS, Inc., Chicago, IL, USA). BCVA and IOP were described as mean±standard deviation (SD). One-way analysis of variance and LSD test were used to evaluate the difference of BCVA, one-way analysis of variance and Dunnett-T3 test were used to evaluate the difference of IOP. $P<0.05$ was considered statistical significance.

RESULTS

In total, 21 eyes of 21 (2 females and 19 males) patients were enrolled. Preoperative and postoperative characteristics were summarised in Tables 1-2. The mean age was 39.6y (range: 15–68y) and the median duration of follow-up was 28mo (range: 24–36mo). All patients suffered severe penetrating trauma resulting in irregular corneal wounds, corneal scarring, corneal oedema, blood-stained cornea, or cataracts without endophthalmitis. RD and VH occurred in 16 eyes (76.2%), RD alone in four eyes (19.0%), and VH combined with IOFB in one eye (4.8%).

The existing severe diffuse dense VH, blood clots, fibrin, and condensation of vitreous fibres were combined in 17 out of the 21 eyes, adhering to the retina and tightly accompanied by different degrees of RD. In the remaining 4 eyes, serous RD with slight VH was found by endoscopy. RD associated with rigid retinal puckers, stiff proliferative membrane, and retinal breaks were found in all the eyes. The vitreous body became opaque with either a blood clot-like or cotton-like appearance. The retina became opaque and thick (especially the retina mixed with the vitreous compound-like blood clots), characterised by oedema and loss of elasticity, followed by stiffening and shortening, resulting in difficulty in recognising the normal retina structure from the abnormal one. Additionally, endoscopy allowed the visualisation of the anterior vitreous base and revealed severe proliferative and inflammatory pathological changes. In all 21 eyes, vitreous fibres were found on the ciliary process to the ora serrata retina with at least two to four quadrants involved. Meanwhile, dense blood clots were also found in 17 eyes with severe VH. The fibrous membrane blood clots were cut, and the retinal retraction was released by EAV. In Stage-III surgery, the fundus was detected by endoscopy in all eyes. Endoscopic examination of the fundus revealed a normal fundus in 9 eyes with a flat retina, scattered retinal laser spots, and focal vascular occlusion, but no optic atrophy, macular atrophy, or proliferative membrane. Endoscopy revealed a flat retina with optic atrophy, macular atrophy, multiple focal vascular occlusions, scattered retinal laser spots, and preretinal membrane in 12 eyes. Among these 12 eyes, mild to moderate membrane retraction of the retina occurred in 9 eyes, and severe membrane retraction of the retina occurred in one eye, while the other two eyes had no membrane retraction. Therefore, silicone oil removal and laser photocoagulation were performed in two eyes (9.5%); silicone oil removal, laser photocoagulation, and IOL fixation were performed in three eyes (14.3%); silicone oil removal, laser photocoagulation, IOL fixation, and penetrating keratoplasty (PKP) were performed in six eyes (33.3%); silicone oil exchange occurred in one eye (4.8%); so a silicone oil tamponade state was maintained in the remaining 10 eyes (47.6%). For these cases, the surgical procedures were performed according to the specific situations and the patient's willingness (Tables 1 and 2).

BCVA improved in 20 eyes at 3mo after the third surgery. The preoperative BCVA was determined to be LP in 13 eyes (61.9%), HM in six eyes (28.5%), and CF in two eyes (9.6%). At 3mo after the third surgery, BCVA was determined to be LP in one eye, HM in four eyes, CF in nine eyes, 20/2000 in three eyes, 20/1000 in three eyes, and 20/500 in one eye. The BCVA was 3.58±0.57 logMAR preoperative, 2.62±0.46 logMAR 3mo after Stage-II surgery, and 2.38±0.60 logMAR 3mo after Stage-III surgery ($P<0.05$). BCVA was not significant differences between 3mo after Stage-II surgery and 3mo after Stage-III surgery ($P>0.05$). IOP was ranging from 5.5 to 7 mm Hg in 12 eyes, and lower than 5 mm Hg in the other nine eyes preoperatively. At 3mo postoperatively after the third surgery, the IOP was normal in 19 eyes. Of the remaining two eyes, one was diagnosed with glaucoma and treated with medication, and one was considered to have chronic hypotony. The IOP was 5.82±0.82 mm Hg preoperative, 11.84±4.28 mm Hg 3mo after Stage-II surgery, and 11.22±3.60 mm Hg 3mo after Stage-III surgery ($P<0.05$); while the IOP had no statistically significant differences between 3mo after Stage-II surgery and 3mo after Stage-III surgery ($P>0.05$). No serious intraoperative complications, *e.g.*, explosive haemorrhage or endophthalmitis, occurred and there were no severe postoperative complications;

Table 1 Pre- and postoperative characteristics of cases

Patient (eye)	Age (y)/sex	Type of injury	Pathology	Stage-I surgery	Time interval between Stage-I and II surgeries	Stage-II surgery (endoscope-assisted)	Time interval between Stage-II and III surgeries (mo)	Stage-III surgery (fundus detection by endoscopy)	Follow-up (mo)	Complications
Case 1 (L)	24/male	Penetrating	Corneal scar, hyphaemia, cataract, RD, VH	CSDS, lens extraction	Within 1wk	Vitrectomy, RLP, SOT	12	FDE, SOR, RLP, PKP, IOLF	24	No
Case 2 (R)	40/male	Penetrating	Corneal oedema, cataract, RD, VH	CSDS, lens extraction	1-2wk	Vitrectomy, RLP, SOT	12	FDE	24	Glaucoma (IOP, controlled by medication)
Case 3 (R)	27/male	Rupture	Corneal scar, cataract, hyphaemia, RD, VH	CSDS, lens extraction	1-2wk	Vitrectomy, RLP, SOT	12	FDE	24	BD
Case 4 (L)	47/male	Penetrating	Corneal oedema, hyphaemia, cataract, RD, VH	CSDS, lens extraction	1-2wk	Vitrectomy, RLP, SOT	12	FDE, SOR, RLP, PKP, IOLF	24	No
Case 5 (L)	42/male	Penetrating	Corneal scar, hyphaemia, cataract, VH, IFOB	CSDS, lens extraction	Within 1wk	Vitrectomy, IFOB removal, RLP, SOT	12	FDE, SOR, RLP, IOLF	24	No
Case 6 (L)	60/male	Penetrating	Corneal oedema, cataract, hyphaemia, RD, VH	CSDS, lens extraction	1-2wk	Vitrectomy, RLP, SOT, SB	12	FDE, SOR, RLP	24	BD
Case 7 (L)	52/male	Penetrating	Corneal scar, cataract, RD	CSDS, lens extraction	1-2wk	Vitrectomy, RLP, SOT, SB	12	FDE	24	No
Case 8 (L)	42/male	Penetrating	Corneal scar, RD, VH, PVR	CSDS, lens extraction, anterior vitrectomy	1-2wk	Vitrectomy, MP, RLP, SOT	12	FDE	36	Chronic hypotony
Case 9 (L)	36/male	Penetrating	Corneal scar, RD, PVR	CSDS, lens extraction	Within 1wk	Vitrectomy, MP, RLP, SOT	12	FDE	24	No
Case 10 (R)	68/male	Penetrating	Corneal oedema, RD, VH, PVR	CSDS, lens extraction	1-2wk	Vitrectomy, MP, RLP, SOT	12	FDE	24	BD
Case 11 (L)	23/male	Penetrating	Corneal scar, cataract, RD, VH	CSDS, lens extraction	Within 1wk	Vitrectomy, MP, RLP, SOT	12	FDE, SOR, RLP	24	No
Case 12 (R)	52/male	Penetrating	Corneal scar, cataract, RD	CSDS, lens extraction, anterior vitrectomy	1-2wk	vitrectomy, MP, RLP, SOT, SB	12	FDE, SOR, RLP, PKP, IOLF	24	No
Case 13 (L)	58/male	Penetrating	Corneal scar, RD	CSDS, lens extraction	1-2wk	Vitrectomy, lensectomy, MP, RLP, SOT	12	FDE, SOR, RLP, PKP, IOLF	24	No
Case 14 (R)	44/male	Penetrating	Corneal scar, hyphaemia, cataract, RD, VH, PVR	CSDS	Within 1wk	Vitrectomy, lensectomy, RLP, SOT	12	FDE, SOR, RLP, PKP, IOLF	24	No
Case 15 (L)	22/female	Penetrating	Corneal scar, hyphaemia, cataract, RD, VH	CSDS	1-2wk	Vitrectomy, MP, lensectomy, RLP, SOT	12	FDE, SOR, RLP, IOLF	36	No
Case 16 (L)	45/male	Rupture	Corneal scar, hyphaemia, cataract, RD, VH, PVR-C	CSDS	3mo	Vitrectomy, lensectomy, PFCL, RLP, MP, SOT	12	FDE, SOR, RLP, IOLF	36	No
Case 17 (R)	44/male	Penetrating	Corneal scar, RD, VH, PVR	CSDS, lens extraction, anterior vitrectomy	1-2wk	Vitrectomy, PFCL, RLP, SOT	12	FDE	24	No
Case 18 (L)	15/male	Penetrating	Corneal scar, hyphaemia, cataract, RD, VH	CSDS	Within 1wk	Vitrectomy, lensectomy, PFLC, RLP, SOT, TA, SB	12	FDE	24	No
Case 19 (R)	20/male	Penetrating	Corneal oedema, corneal scar, RD, VH	CSDS, lens extraction	Within 1wk	Vitrectomy, MP, RLP, SOT (heavy oil), SB	12	FDE, Silicone oil exchange	28	No
Case 20 (R)	36/female	Penetrating	Corneal oedema, hyphaemia, cataract, RD, VH	CSDS, lens extraction	Within 1wk	Vitrectomy, MP, PFLC, RLP, SB, SOT (heavy oil)	12	FDE, SOR, RLP, PKP, IOLF	36	No
Case 21 (L)	35/male	Penetrating	Cataract, corneal scar, RD, VH	CSDS	1-2wk	Vitrectomy, lensectomy, RLP, SOT (heavy oil)	12	FDE	24	No

L: Left eye; R: Right eye; RD: Retinal detachment; VH: Vitreous haemorrhage; CSDS: Corneal scleral debridement and suture; RLP: Retinal laser photocoagulation; SOT: Silicone oil tamponade; FDE: Fundus detection by endoscopy; SOR: Silicone oil removal; PKP: Penetrating keratoplasty; IOLF: Intraocular lens fixation; IOP: Intraocular pressure; BD: Band degeneration; IFOB: Intraocular foreign body; SB: Scleral buckling; PVR: Proliferative vitreoretinopathy; MP: Membrane peeling; PFCL: Perfluorocarbon liquid; TA: Triamcinolone acetonide injection.

Table 2 Surgical parameters

Surgical options	Eyes (%)
Stage-I surgery	
CSDS	5 (23.8)
CSDS, lens extraction	13 (61.9)
CSDS, lens extraction, anterior vitrectomy	3 (14.3)
Time interval between Stage-I and II surgeries	
Within 1wk	12 (57.1)
Within 2wk	8 (38.1)
More than 2mo	1 (4.8)
Stage-II surgery (endoscope-assisted)	
Vitrectomy, RLP, SOT	4 (19.0)
Vitrectomy, RLP, SOT, SB	2 (9.5)
Vitrectomy, RLP, SOT, IFOB removal	1 (4.8)
Vitrectomy, RLP, SOT, MP	4 (19.0)
Vitrectomy, RLP, SOT, MP, SB	2 (9.5)
Vitrectomy, RLP, SOT, lensectomy	2 (9.5)
Vitrectomy, RLP, SOT, lensectomy, MP	2 (9.5)
Vitrectomy, RLP, SOT, lensectomy, MP, PFCL	1 (4.8)
Vitrectomy, RLP, SOT, PFCL	1 (4.8)
Vitrectomy, RLP, SOT, lensectomy, PFCL, TA, SB	1 (4.8)
Vitrectomy, RLP, SOT (heavy oil), SB, MP, PFCL	1 (4.8)
Time interval between Stage-II and III surgery	
12mo	21 (100)
Stage-III surgery	
FDE alone	9 (42.8)
FDE, RLP, SOR	2 (9.5)
FDE, SOR, RLP, IOL fixation	3 (14.3)
FDE, SOR, RLP, IOL fixation, PKP	6 (28.6)
Silicone oil exchange	1 (4.8)

CSDS: Corneal scleral debridement and suture; RLP: Retinal laser photocoagulation; SOT: Silicone oil tamponade; SB: Scleral buckling; IFOB: Intraocular foreign body; MP: Membrane peeling; PFCL: Perfluorocarbon liquid; TA: Triamcinolone acetonide injection; FDE: Fundus detection by endoscopy; SOR: Silicone oil removal; IOL: Intraocular lens; PKP: Penetrating keratoplasty.

however, band keratopathy occurred in three eyes. No eyes were enucleated during the follow-up period (Tables 3 and 4).

Case 19 was a 20-year-old male patient who presented with a penetrating injury to the right eye. The eye showed irregular semi-circular corneal laceration from 12 o'clock to 9 o'clock associated with cataract, and the fundus showed RD and VH. The BCVA of the right eye was LP preoperatively and CF 3mo after the third surgery. IOP of the right eye 3mo after the third surgery increased from 5.0 mm Hg preoperatively to 8.9 mm Hg postoperatively. His right eye had a corneal scleral fissure, which was sutured and underwent lens-extraction surgery immediately after injury. Subsequently, EAV was performed 1wk after the trauma. During vitrectomy, it was hard to visualise the ocular structure clearly with an irregular corneal injury, while endoscopy grants access to the inner ocular structure. Using EAV, MP was performed to release the traction between the retina and membrane. Scleral buckling was applied for the retina as it remained stiff and rigid and shrank. Following this, retinal laser photocoagulation and silicone oil tamponade (heavy oil) were performed to spread out the retina. Endoscopy revealed dense VH, blood clots, and vitreous materials adhered closely to the retina. The optic nerve head, macula, and retina could not be visualised at first but appeared as the VH was cleared. At 12mo postoperatively, endoscopic examination of the fundus revealed that the posterior retina was reattached with the white sheets of proliferative membrane in the macula and superior peripheral retina. As the posterior membrane was proliferative, silicone oil was suggested to retain it in the vitreous cavity. Therefore, silicone oil exchange and MP were performed at this examination (Figure 1).

Table 3 Preoperative and postoperative BCVA and IOP

Parameters	Preop.	3mo after Stage-II surgery	3mo after Stage-III surgery
BCVA			
LP	13	1	1
HM	6	6	4
CF	2	14	9
>CF	0	0	7
IOP (mm Hg)			
≤5	9	1	1
5-7	12	1	0
>7	0	19	19

BCVA: Best corrected visual acuity; IOP: Intraocular pressure; CF: Counting fingers; HM: Hand motion; LP: Light perception.

Table 4 Comparison among preoperative and postoperative BCVA and IOP

Parameters	Preop.	3mo after Stage-II surgery	3mo after Stage-III surgery
BCVA	3.58±0.57	2.62±0.46[a]	2.38±0.60[a]
IOP	5.82±0.82	11.84±4.28[a]	11.22±3.60[a]

[a]*P*<0.001 *vs* preop. BCVA: Best corrected visual acuity; IOP: Intraocular pressure.

Case 20 was a 32-year-old female patient who presented with a penetrating injury to the right eye. The eye showed two parallel corneal lacerations from 3 o'clock to 8 o'clock on the corneal limbus, associated with corneal oedema, hyphaemia, and cataract, and the fundus indicated RD and VH. The BCVA of the right eye was LP preoperatively and 3mo after the third surgery was 20/500, while the IOP of the right eye increased from 5.0 mm Hg preoperatively to 10.5 mm Hg 3mo after the third surgery. Her corneal scleral fissure was sutured and lens-extraction surgery was undergone immediately after injury. Vitrectomy and MP, retinal laser photocoagulation, silicone oil tamponade, scleral buckling, and PFCL were performed under endoscopic visualisation in Stage-II surgery. Endoscopy revealed VH and vitreous opacity, retinal breakage

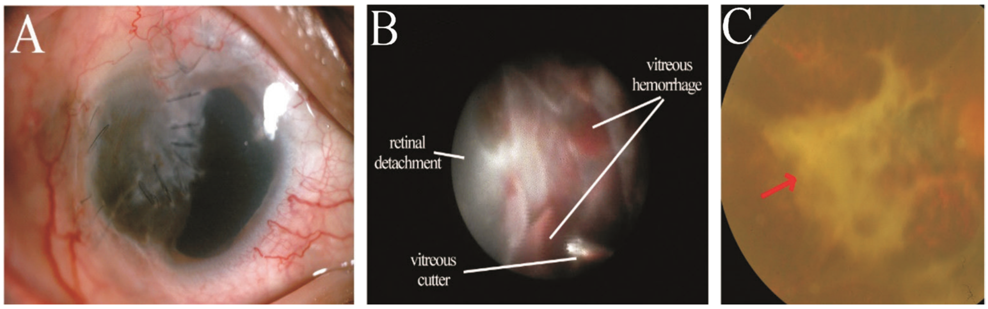

Figure 1 Case 19 with a penetrating injury of the right eye A: Aphakia and aniridia 1mo after Stage-I surgery. The conjunctival congestion, irregular corneal wound, corneal suture, and corneal neovascularisation were located in the temporal region and superior limbus region. B: Image from endoscopy-assisted vitrectomy showed the inferior retina; the vitreous cutter was cutting the dense vitreous haemorrhage. Vitreous blood clots, detached retina, and retina puckers associated with the membrane were observed. C: Image from endoscopy-assisted vitrectomy showed the posterior fundus 12mo after Stage-II surgery. The posterior retina was flat with scattered retinal laser spots and white sheets of preretinal membrane (the red arrow). The optic nerve (the white arrow) was normal, and the macula was covered by the preretinal white membrane.

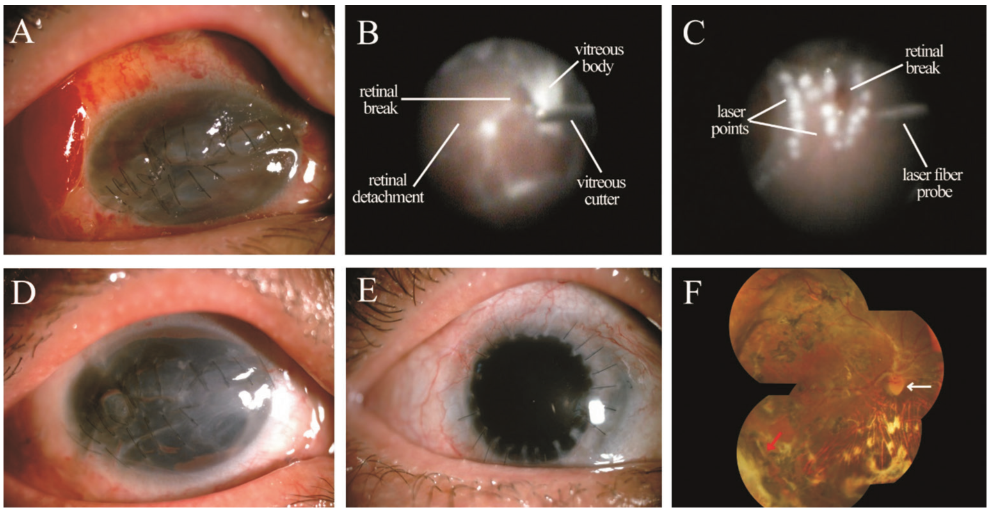

Figure 2 Case 20 with penetrating injury of right eye A: Aphakia after Stage-I surgery. An irregular corneal wound, corneal edema, and corneal suture were located along the interpalpebral zone with conjunctival haemorrhage and conjunctival oedema. B: Image from endoscopy-assisted vitrectomy showed the fundus in the superior peripheral retina with retinal detachment, retinal break, vitreous opacity, and vitreous haemorrhage. The vitreous cutter incised the vitreous opacity. C: Image from the endoscopy-assisted retinal laser photocoagulation showed the fundus in the nasal-superior peripheral retina. D: Aphakia and aniridia 3mo after Stage-I surgery with corneal suture and leukoma. E: 6mo after penetrating keratoplasty, the corneal graft was transparent. F: Image from endoscopy-assisted vitrectomy showed the fundus after all operations. The retina was flat, and the macula can be seen with scattered retinal scarring, retinal pigmentation, and retinal laser spots. The white arrow indicated the optic nerve, and the red arrow showed the crest of the scleral buckling.

and proliferative membrane in the superior peripheral retina. Following successful vitrectomy and relief of retinal traction, PFCL was used to flatten the retina and retinal laser photocoagulation, silicone oil tamponade, and scleral buckling were performed as the peripheral vitreous was cleared. At 12mo postoperatively, endoscopic examination of the fundus revealed that the fundus was flat with scattered retinal laser spots, with a slightly proliferative preretinal membrane. Therefore, combined surgery of silicone oil removal, retinal laser photocoagulation, and PKP was performed (Figure 2).

DISCUSSION

In our case series we observe the utility of EAV for severe ocular penetrating trauma with corneal opacity. In the study it showed the successful repairment of ocular structure in all the 21 eyes; and BCVA improved in 20 eyes after all the surgery except one eye maintained LP, the IOP raised to normal in 19 eyes with one eye of glaucoma controlled by medication and one eye of chronic hypotony. Obviously, EAV is an effective and beneficial surgical approach for those severe ocular trauma which could be easily accessible to the fundus, and it is helpful to prognosticate the outcome and offer further surgical options by evaluating the condition of fundus especially the state of the retina, the vessels and the optic disc[12-14]. It is not mandatory to perform the surgery by 20-guage endoscope. As mentioned before, the intraocular endoscope has its own optical dust illuminating, now the gradient index system we used is produced by Poly Diagnost in Germany, with the 20-gauge endoscope having 10 000 pixels and 110° FOV. It can provide a high-definition images. When using 23-gague endoscope, the definition degree of 6000 pixels, was not so clear to distinct and observe the structures in the intraocular. The use of EAV is challenging, and has a steep learning curve. The operator should indirectly look at the surgical field on the monitor which requires training to adapt to the pseudo stereopsis, rather than traditional true stereopsis. Besides, the side-on intraoperative perspective requires the ability to discern the endoscope's orientation and manually control the probe tip, which requires precise hand-eye coordination. So, it is impossible to operate the surgery bimanually as one hand must control the endoscope, and important to center the target area in the FOV during the surgery. Obviously, it makes much easier to operate the surgery when the corneal limbal-tunnel incision were made at the 9-12 o'clock. As known, severe ocular penetrating trauma may lead to inflammation, membrane proliferation, or even endophthalmitis, so timely vitrectomy is necessary. Most researchers had reached a consensus that, vitrectomy should be performed as soon as possible, and the operation was arranged between 1 to 2wk when accompanied with vitreous haemorrhage, while within 5d if endophthalmitis is confirmed[15-17]. However, in severe ocular penetrating trauma, it is difficult to perform complete vitrectomy due to visual obstruction by irregular corneal laceration or other conditions such as media opacity by conventional microscope or wide-angle microscope. Moreover, membrane proliferation occurs in a scattered manner in severe ocular trauma, especially in the anterior vitreous base, which further restricts fundus visualisation[18-19]. Under such condition, inadequate vitrectomy is a common phenomenon which contributing to PVR, a-PVR, recurrent RD or other complications. However, endoscopy is an effective tool to manage such surgeries with good visualisation for the treatment of eyes following trauma.

The combination of temporary keratoprosthesis with vitreoretinal surgery and penetrating keratoplasty (PKP) has been reported to be beneficial for the repair of anatomical structures of the eye with concomitant improvement of visual acuity; in some cases, oteo-odonto-keratoprosthetic surgery may be considered[16,20-24]. However, there are some concerns regarding the use of these procedures. First, there is no consistent supply of donated corneal material; hence, the waiting time for corneal graft materials might be long, which could lead to the development of PVR. PVR directly influences the prognosis of combined surgery as well as the outcomes of retinal anatomy, visual acuity, and severity of PVR, which determines the possibility of silicone oil removal[20-21]. Second, during temporary keratoplasty (TKP) or PKP, the risks of suprachoroidal haemorrhage and ocular infection, which are both major causes of vision loss after PKP, are increased using the ocular open-sky method[22]. Third, complications such as corneal graft failure, corneal graft rejection, glaucoma, and inflammation may occur postoperatively. Corneal graft failure can occur in cases of ocular hypotony or phthisis; furthermore, there have been many reports indicating the high risk of graft failure when ocular silicone oil tamponade is performed, because the contact between the silicone oil and endothelium may contribute to graft failure[16,23]. If there is prolonged direct contact of silicone oil with the cornea, there is a significantly increased risk of endothelial decompensation, known as silicone oil keratopathy. The factors that influence the outcomes of combined TKP with vitreoretinal surgery and/or PKP are complex, so it may be beneficial to handle the posterior segment first. Thereafter, PKP can be performed in a subsequent surgical procedure after successful correction of retinal anatomical structures and severe corneal pathology. In our case series, all the eyes had severe ocular trauma and had severe degree of cornea injury. It was obvious that the state of the cornea was not good, or to some extent all the eyes were suggested to accept PKP to gain a much more visual acuity if there was a chance. Although silicone oil may harm the scarred cornea, the pathological cornea would accepted PKP in some day if the visual acuity could improve. Therefore, treatment using vitrectomy and silicone oil tamponade was conducted due to complicated intraocular pathologies.

Based on the above considerations, we recommend EAV surgery for treatment. The use of this technique has been increasingly recognised in recent years as a supplementary surgical method[7,9,25]. Sabti and Raizada[26] reported a series which demonstrated that ophthalmic endoscopy provides a clear view to conduct pars plana vitrectomy, overcoming the problems of media haze or non-availability of donor corneas for simultaneous PKP. In their case series, nearly all eyes showed improvements in vision and severe PVR was avoided. Farias *et al*[27] demonstrated that endoscopy enables direct visualisation of the posterior segment, thus offering information about the visual potential in patients intended for PKP.

In our case series, the surgical strategy of lens extraction was determined by the position and the transparency of the lens. Extra capsular extraction of lens or intra-capsular extraction of lens were accepted in all cases because of the ruptured capsule or the lens dislocation in Stage-I surgery. And some patients were aphakic eyes because the lens was extracted in the hospital at their first visit. In Stage-II surgery, the IOL was fixed by suturing in the ciliary sulcus by Prolene PC-9 (Alcon) with an intraocular irrigation after surgeries of posterior ocular segment[28]. When operating the surgery of suture fixation of

IOL, a conjunctival flap with the fornix as the basement was located at 1 and 7 o'clock with the incisions were selected on the scleral about 1.5 mm far from the limbus. By this, the haptics of the IOL was fixed in the ciliary sulcus, with the knot was hidden in the scleral tunnel incision.

As we known, in our cases EAV ensured that all eyes underwent surgery in a timely manner and that the duration of surgery was reduced by avoiding the need for keratoprosthesis. All 21 eyes underwent successful vitrectomy, retinal laser photocoagulation, and silicone oil tamponade by endoscopy. Therefore, the VH, blood clots, vitreous fibres, and stiff membranes were cleared up, and retinal breakages and RD were restored. In addition, in the anterior vitreous base, pathological anterior vitreous fibres, blood clots, and proliferative membrane covering the ciliary process or adhering to the peripheral retina were cut by vitreous cutters using endoscopy. Among those cases, 10 eyes required additional management using MP for the retinal membrane, six required scleral buckling, and four underwent PFCL to flatten the retina. Finally, these retinas were flattened in cases of corneal opacity. without endoscope, it is really a tough work to perform the operation thoroughly, or without a relatively good prognosis of ocular structure and visual function.

Direct fundus examination by endoscopy enabled us to determine the eyes that required further surgeries, and the eyes that were not suitable candidates. As mentioned before, by endoscopy it revealed that 9 eyes had relatively stable fundus, while 12 eyes had atrophic fundus of vascular occlusion, macular atrophy or optic atrophy which contained 9 eyes of mild membrane traction. So different surgical strategies were applied for different cases on specific situation. After the evaluation, silicone oil exchange or removal, penetrating keratoplasty was also considered. After all operations, the anatomical structures of the eyes were restored in all eyes, BCVA improved in 20 eyes at the last visit, and IOP was normal in all eyes except one with secondary glaucoma in which IOP was controlled with medication, and one eye of chronic hypotony. As regard to BCVA, it revealed that BCVA increased obviously in cases of those who accepted surgeries of silicone oil removal, IOL fixation and PKP, while other cases showed little changes in BCVA mainly for the atrophic fundus detected by endoscope without further operation as well as corneal opacity. Inflammation and the development of PVR in traumatic eyes can persist for months or years for which long-standing or permanent silicone oil tamponade is recommended to preserve vision and prevent ocular atrophy. Although we observed mild deterioration of the corneal band degeneration in three eyes, which may have been caused by silicone oil, stability of the ocular structure remained. In one case of chronic hypotony, we concluded that the severe trauma caused serious damage to the ocular structure, leading to proliferative membrane traction of the peripheral retina, cyclitic membrane, and atrophied ciliary body, and consequent reduction of aqueous humour production. In such conditions, another surgery of membrane peeling and releasing and permanent silicone oil tamponade was recommended and was administered in the present study.

EAV and other combined surgeries can enable rehabilitation and preservation of eyes with severe ocular pathologies, especially corneal opacity. Although this does not suggest that endoscopy should be used as a routine surgery for ocular trauma, it could be a useful adjunct tool for surgeons tackling difficult or severe cases of ocular trauma and has value by enabling clear observation of the posterior segment for evaluation of the visual potential and inform further surgical decisions, as shown in our study.

The main limitation of this study was its small sample size. Trauma is a major factor influence the final outcome of vision and ocular function at some extent. Further studies with longer follow-up periods are needed to investigate the long-term efficiency of the technique.

In conclusion, EAV is a useful adjunct for the management of severe ocular trauma with visual obstruction as a result of opaque media, such as corneal opacity, a microcornea, or a small pupil, especially when there is no available donor cornea for PKP. Endoscopy enables easy access to the intraocular structures, as well as observation of the posterior segment with media opacity. These advantages could inform appropriate surgical decisions and facilitate accurate visual potential prognosis. Thus, we expect EAV to become an increasingly valuable technique in the field of ocular surgery.

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