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ORIGINAL RESEARCH

Segmentation and removal of fibrovascular membranes with high-speed 23 G transconjunctival sutureless vitrectomy, in severe proliferative diabetic retinopathy

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Aim: To evaluate the effectiveness and safety of high-speed (5,000 cuts per minute) 23 G transconjunctival sutureless vitrectomy (TSV) in severe diabetic fibrovascular proliferation (DFVP).

Patients and methods: In this retrospective consecutive case series, patients who underwent 23 G TSV for severe DFVP between October 2011 and March 2014 at our institution were evaluated. 23 G TSV was performed with a high-speed (5,000 cuts per minute) cutter without a chandelier light.

Results: The mean follow-up period was 8 months (range: 4–23 months). Of the 27 eyes of 27 patients, 14 eyes (52%) underwent concomitant phacoemulsification with posterior chamber intraocular lens implantation, nine eyes (33%) were pseudophakic, and four eyes were phakic (15%). DFVP was removed with ease in all, and visual acuity was improved in 18 (67%) eyes. Iatrogenic retinal tear was observed in four eyes (15%) and treated successfully during surgery. Suture placement to a single sclerotomy was performed in eight eyes (30%). Postoperative intraocular hemorrhage was observed in five eyes (18%). Cataract formation was observed in two of the four phakic eyes. Three (11%) patients had postoperative intraocular pressure rise. Postoperative hypotony (≤6 mmHg) and endophthalmitis were not observed in any eye.

Conclusion: The segmentation and removal of fibrovascular membranes with high-speed 23 G TSV seems to be a safe and easy method in severe diabetic eye disease.

Keywords: diabetic fibrovascular proliferation, transconjunctival sutureless vitrectomy, high speed

Introduction

Traditionally, 20 G vitrectomies are the most practiced vitrectomy for a variety of vitreoretinal diseases, including diabetic fibrovascular proliferation (DFVP).[1] The last 30 years have been very beneficial for the improvement of vitrectomy systems. When compared to the old 20 G vitrectomy systems, which use 0.89 mm sclerotomies, the new techniques use smaller sclerotomies and are less complicated.[2]

Fujii et al first introduced 25 G transconjunctival sutureless vitrectomy (TSV) in 2002 following a self-sealing sclerotomy that was described by Chen.[3,4] However, usage of 25 G TSV presented some problems, including the significant flexibility of the instruments, resulting in reduced manipulation, inadequate illumination, and reduced lumen of the microcannula for fluid flow.[5–7] In 2005, Eckardt[8] presented a 23 G TSV

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and solved the flexibility problems, allowing greater ocular rotation and ability to apply it to more complicated vitreoretinal diseases, such as DFVP. Several studies reported the safety and effectiveness of the 23 G pars plana vitrectomy (PPV).[9–12]

Recently, new vitrectomy systems with ultrahigh-speed cut rates (5,000 cuts per minute [cpm]) and duty cycle controls have become available.[13] The benefits of these new systems are that a greater cut rate reduces vitreous turbulence by allowing only small pieces of vitreous to enter the port, resulting in little retinal traction. In addition, a greater cut rate and a maximum port opening increase the efficacy of the system.[14–17]

The aim of this study was to evaluate the effectiveness and safety of segmentation and removal of membranes with ultrahigh-speed (5,000 cpm) 23 G TSV in eyes with severe DFVP.

In conclusion, fibrovascular proliferation is a challenging complication of severe diabetic eye disease. Segmentation and removal of membranes with ultrahigh-speed 23 G vitrectomy with 5,000 cpm seems to be effective in the treatment of this condition with an acceptable intra- and postoperative complication rate.

Patients and methods

Patients

In this retrospective noncomparative study, we inspected 27 eyes of 27 consecutive patients who underwent high-speed (5,000 cpm) 23 G TSV with segmentation technique for severe DFVP between October 2011 and March 2013 at the Department of Ophthalmology in Namik Kemal University, School of Medicine.

The research was conducted in accordance with the Declaration of Helsinki, and all patients signed a written informed consent after receiving an explanation of possible consequences of the operations.

Inclusion/exclusion criteria

Inclusion criterion was patients with diabetic fibrovascular membranes that threaten the macula. Threat to the macula was considered as fibrovascular membranes close to the avascular foveal zone inside and over the vascular arcade. Assessment of macula-threatening lesion was made by clinical examination and noted routinely by the same experienced surgeon (FH) before the operations. The exclusion criteria included history of prior vitrectomy, glaucoma filtration surgery, intractable glaucoma, and vitreous hemorrhage (VH) without fibrovascular proliferation. All patients received anterior segment examination, intraocular pressure measurement with applanation tonometry, a best-corrected Snellen visual acuity measurement, and biomicroscopic evaluation with fundus noncontact lenses. All eyes without visualization of fundus underwent B-scan ultrasonography. All Snellen visual acuities were converted into logarithm of the minimum angle of resolution units. Intraocular pressure levels ≥21 mmHg were accepted as elevated intraocular pressure.

Methods

Surgical technique

All the operations were performed by the same surgeon (FH). The two-step 23 G vitrectomy system (Stellaris PC; Bausch and Lomb, Rochester, NY, USA) was used in all cases. When the patient had a significant cataract, combined phacoemulsification and intraocular lens implantation were performed through a 2.8 mm clear corneal incision before the scleral incision for vitrectomy was made. Insertion trocars were implanted in the superotemporal, inferotemporal, and superonasal quadrants, and microcannulas were implanted through them 3–3.5 mm posterior to the limbus. A 23 G microvitreoretinal blade was inserted tangentially at an angle of ~30°, parallel to the limbus. Microcannulas were inserted transconjunctivally with the help of the insertion trocars in the inferotemporal, superotemporal, and superonasal quadrants, 3.5 mm posterior to the limbus. 23 G microvitreoretinal blade was used at an angle of 30°, tangent to the limbus. The inferotemporal quadrant was used for infusion cannula, and other entry sites were temporarily closed by plugs. The high-speed vitrectomy probe (Bausch and Lomb) of the surgical system (Stellaris PC; Bausch and Lomb) with a cutting rate of 5,000 cpm and vacuum levels of 150–300 mmHg was used during PPV. Bottle height for operations was 40 cm. After core vitrectomy, the vacuum level was settled a 200 mmHg, and peripheral vitreous and tractions between the anterior and posterior vitreous were removed. Posterior vitreous detachment was resolved using a silicone-tipped cannula by passive aspiration and then continued 360° peripherally. Endoilluminator probe was used as a second hand, and a cleavage was created with either a membrane pick or a 25 G needle through the membrane. Shaving of the membranes at the retina plane with the high-speed vitrectomy was performed under a wide-angle viewing system using a vacuum level of 100–150 mmHg and a cutting rate of 5,000 cpm. At the end of each surgery, air–fluid exchange was always carried out, and endolaser treatment and endotamponades were performed when required. For standard cases, we used air as endotamponade,

but for complicated cases (intraoperative retinal tear and extensive fibrovascular tissue dissection), perfluoropropane (C3F8) gas or silicone oil was used. In group 1, air was selected as a tamponade, whereas in group 2 and eyes with iatrogenic tear, C3F8 gas was selected as a tamponade, and if the patient had a contraindication for gas (flying, climbing, etc), silicone oil was selected as a tamponade. At the end of the operation, microcannulas were gently removed from the eye. The conjunctival tissue over the sclerotomy was displaced to avoid the formation of a fistula. A little bit of massage with a muscle hook was used to ensure there was no leakage. The sclerotomy site was sutured with 7/0 Vicryl, if any sign of leakage was detected, such as a bleb formation or hypotony, after the application of 20 seconds compression three times. Corticosteroid (dexamethasone, 4 mg) and antibiotic (cefazolin, 50 mg) were injected into the subconjunctival space. Topical antibiotics and steroids were prescribed postoperatively for 1 month.

Main results were visual and anatomical outcomes, and then as secondary results, postoperative and intraoperative results were recorded. Time points for postoperative examinations were first day, first week, first month, third month, and 3 months. However, not all the patients were present at each call. All patients were present only at postoperative first day visit.

Statistical analysis

Statistical analysis was performed using the PASW Statistics (SPSS for Windows, version 18.0, SPSS, Chicago, IL, USA). *P*-values of <0.05 were considered as statistically significant.

All the patients were informed about possible risks of the treatment, and an informed consent was prepared according to the Declaration of Helsinki. Namık Kemal University School of Medicine Local Ethical Committee waived the requirement to obtain approval from institutional review board for retrospective studies.

Results

The clinical characteristics of the patients are summarized in Table 1. The mean age at surgery was 61.9 years (range: 46–80 years). Male to female ratio was 15:12 (55%:45%). The mean follow-up period was 8.3 months (range: 4–23 months). DFVP was removed with ease from all eyes. Fourteen eyes (52%) underwent concomitant phacoemulsification with posterior chamber intraocular lens implantation, nine eyes (33%) were pseudophakic, and four eyes were phakic (15%). Eleven eyes (41%) were given intravitreal bevacizumab (IVB) (Altuzan®, Roche®, Basel, Switzerland) within 1 week prior to surgery. Nineteen eyes (70%) received air, six eyes (22%) received C3F8 gas, and two eyes (8%) received silicone oil as endotamponade. Suture placement for a single sclerotomy was performed in eight (30%) eyes at the end of the surgery. Suture placement was not required for any eyes during the postoperative follow-up period.

Visual acuity was between hand motions and 0.5 preoperatively (median counting fingers) and hand motions and 0.7 (median 0.1) postoperatively. Visual acuity improvement was achieved in 18 eyes (67%). Visual acuity remained the same in eight eyes (30%) and decreased in one eye (3%) due to postoperative cystoid macular edema. Mean postoperative intraocular pressure was 14.8±6.7 mmHg preoperatively and 15.0±6.6 mmHg postoperatively ($P>0.05$). Any rise in IOP was treated with medication. Postoperative 6-month visual acuity and IOP were 0.90±0.55 logarithm of the minimum angle of resolution and 11.49±3.1 mmHg, respectively. Combined surgery had 0.12 Snellen visual acuity gain at postoperative month 6, and PPV alone had 0.18 Snellen visual acuity gain at postoperative month 6. Postoperative complications were five intravitreal hemorrhages, and four of the hemorrhages did not use bevacizumab.

Postoperative intraocular hemorrhage was observed in five eyes (18%). In four of these eyes, hemorrhage resolved spontaneously, whereas secondary wash-out vitrectomy was performed in the other eye. Cataract formation (two of the four phakic eyes), iatrogenic retinal tear (15%), and rise in IOP (11%) were the postoperative complications. Postoperative hypotony (≤6 mmHg) and endophthalmitis were not observed in any eye.

Discussion

Neovascularization with or without fibrous proliferation is the hallmark of proliferative diabetic retinopathy (PDR).[18] Contraction of the proliferative fibrovascular membranes causes hemorrhages and retinal detachment, which may lead to blindness if not properly treated.[19,20] Surgical treatment for fibrovascular membranes may relieve tractions and improve vision. The most effective and proven treatment for the complications of PDR is PPV, with good success.[21–25] There are different dissection techniques for proliferative fibrovascular membrane surgery some of the surgeons prefer to use the en bloc excision of membranes, and some of them use the segmentation or delamination techniques. High-speed vitrectomy has got several advantages, but the mostly accepted benefit is less traction and less retinal detachment. We preferred to use segmentation and removal of membranes with high-speed cutter in all cases.

Table 1 Preoperative, intraoperative, and postoperative clinical characteristics of eyes that received 23 G transconjunctival sutureless vitrectomy with high-speed (5,000 cpm) cutter

No	Age	Sex	Follow-up time (months)	Preoperative VA	Postoperative VA	Phacic	Combined Phaco-PPV	Preoperative IVB	Suture	Tamponade	Complications
1	80	M	6	HM	0.7	N	N	N	N	Air	N
2	71	F	9	CF	0.05	Y	Y	N	Y	Air	Glaucoma
3	59	F	9	HM	CF	Y	N	N	N	C3F8	Cataract
4	58	F	11	0.5	0.6	N	N	N	Y	Silicone oil	N
5	51	M	4	0.3	0.2	N	N	Y	N	Air	Glaucoma
6	46	F	6.5	HM	0.1	Y	Y	N	N	C3F8	IRT
7	63	M	14.5	CF	0.2	N	N	N	Y	C3F8	N
8	66	M	5	CF	CF	N	N	N	N	Air	N
9	57	F	6	0.1	0.1	Y	Y	Y	N	Air	N
10	60	F	8	CF	0.3	Y	Y	N	N	Air	VH
11	57	M	7	0.1	0.4	Y	Y	N	N	Air	N
12	49	M	9.5	0.1	0.2	Y	Y	Y	N	Air	N
13	78	M	6	CF	0.05	Y	N	Y	N	Air	Cataract
14	78	M	5	CF	0.05	Y	Y	Y	N	Air	N
15	54	F	9	HM	HM	Y	Y	N	Y	Air	VH
16	51	F	19	CF	0.05	Y	Y	Y	N	Air	VH
17	63	M	11	0.1	0.1	Y	N	Y	Y	C3F8	IRT
18	64	M	12	0.05	0.05	Y	Y	Y	Y	Silicone oil	Glaucoma
19	62	F	8	HM	0.2	N	N	N	N	Air	VH
20	61	M	6	0.2	0.2	Y	Y	Y	Y	C3F8	N
21	65	M	11	CF	0.1	Y	Y	N	N	Air	N
22	60	M	5	CF	0.4	Y	N	Y	N	C3F8	N
23	63	F	7	0.1	0.1	Y	Y	N	N	Air	VH
24	63	F	13	HM	0.05	N	N	Y	N	Air	N
25	66	M	6	HM	0.3	Y	Y	N	N	Air	IRT
26	57	F	6	0.2	0.2	N	N	N	Y	Air	N
27	69	M	5	CF	0.1	N	N	N	N	Air	IRT

Abbreviations: C3F8, perfluoropropane; CF, counting fingers; F, female; HM, hand motions; IRT, iatrogenic retinal tear; IVB, intravitreal bevacizumab; M, male; N, no; Phaco-PPV, phacoemulsification-pars plana vitrectomy combined surgery; VA, visual acuity (Snellen); VH, vitreous hemorrhage; Y, yes.

All surgical innovations for vitrectomy surgeries aimed to find the less invasive and faster method. Of late, the advent of 23 G and 25 G instruments has begun to change the importance of conventional 20 G vitrectomy with its benefits, such as faster surgery and quicker healing time.[4,5,26,27] TSV has several advantages over traditional 20 G vitrectomy.[6,8,9,27] Smaller incisions result in faster wound healing, thanks to self-closing sclerotomy (without peritomy). All these result in less scarring on the conjunctiva, and less patient disturbance, postoperative inflammation, and astigmatism.[28–31]

Although TSV was recommended for macular pathologic features or simple VH because of the limited designs and fragility of small-gauge instrumentation in the initial stage, recent invention of rigid instrumentation and bright light sources has expanded the indications for TSV to comprise more complex vitreoretinal disorders, such as PDR.[6,9,10,32,33] TSV should be more suitable than traditional 20 G PPV for treating PDR because the conjunctiva-preserving nature of TSV allows repeated vitrectomy or filtering surgery that may be needed in patients with diabetes complicated with neovascular glaucoma even after vitrectomy. Less postoperative inflammation associated with TSV may facilitate early visual recovery in PDR as well as in macular diseases. However, it still remains a concern whether complex intraocular manipulations, such as fibrovascular membrane dissection and hemostasis in diabetic vitrectomy, can be managed steadily using small-gauge instrumentation.[34] Besides, one of the main obstacles of small-gauge vitrectomy is longer vitrectomy time (because of longer bulk vitreous removal) compared to 20 G vitrectomy systems,[4,5] which equalizes the saved time for wound opening and closing.[14,35–37] Along with this, dense hemorrhages and epiretinal membranes and tight vitreous strands may be more difficult to remove.[13] Recently, to overcome these problems, new vitrectomy systems with high-speed cut rates (5,000 cpm) and duty cycle controls have become available. As for the benefits of this system, 5,000 cpm cut rate results in a less vitreous turbulence with small pieces of vitreous aspiration, the chance to work with a maximum port opening while also using higher cutting rate and minimal traction on retinal surface.[14–17]

Vitreous is a kind of gelatinous fluid formed of 2% protein and 98% liquid and bigger particles may occlude port but the advantage of higher cut rate leads to aspiration of smaller pieces without causing serious port occlusion.[16,38] Moreover, for less tractions on retina, "port-based flow-limiting" vitrectomy leads to a decreased flow (volume per open–close cycle) and greater fluidic stability.[13] During our surgeries, we observed that high-speed vitrectomy (5,000 cpm) provides maximum fluidic stability, thanks to port-based flow limitation. Moreover, high-speed cutter diminishes the need for bimanual technique with chandelier light.

Few studies have evaluated the safety and efficacy of the TSV for severe complicated vitreoretinal diseases.[33,39–41] Oliveira and Reis[40] reported the surgical results of 20 cases treated with the 23 G TSV and silicone oil tamponade. Altan et al[41] reported the surgical outcome of 25 G TSV for the diabetic tractional detachment, which included six cases of bimanual technique. Park et al[42] reported the short outcome of bimanual 23 G TSV for patients with complicated vitreoretinopathies, including PDR. The anatomical success rate ranged from 72.2% to 100%, and the rate of visual impairment ranged from 61.5% to 85% in these previous studies. In this study, with a limited case series, DFVP was removed with ease in all eyes by 23 G high-speed cutter, and visual acuity improvement was achieved in 67% of eyes. Recently, Rizzo et al[13] reported a study between a standard new ultrahigh-speed 25 G system (Alcon Constellation, Fort Worth, TX, USA; 5,000 cpm) and 25 G TSV (Alcon Accurus, 1,500 cpm) in the treatment of different vitreoretinal diseases. They showed that iatrogenic retinal breaks and duration of vitrectomy time were significantly shorter in the new high-speed 25 G group. However, a direct comparison between each of the reports is not possible because these studies were limited by small descriptive case series with short-term follow-up, limited information about the severity of the vitreoretinal disease, different patient populations, and the use of different surgical methods. Visual outcomes and anatomical results of PDR are mostly unpredictable.[43] Anatomical outcomes are mostly related to vitreoretinal adhesion, degree of fibrous tissue, and high rates of iatrogenic tears, which complicate the surgery.[44–46] Some patients needed silicone oil, while some others had preceding ischemic maculopathy and macular dysfunction as a result of long duration of macular traction.[25,45,47]

Although vitreoretinal techniques have evolved, the incidence of iatrogenic retinal breaks is still significantly high. Simple VHs to complex DFVP ratio was 12%:78% for iatrogenic tears.[48,49] Issa et al[50] compared the retinal breaks observed during 23 G TSV vs conventional 20 G PPV for PDR and reported that there was a significant reduction in the incidence of peripheral retinal breaks in the 23 G group (5%) using the Alcon Accurus and Constellation cutters with higher cut rates (2,500/5,000 cpm) compared to 20 G group (16%). According to a study reported by Park et al,[2] retinal breaks were observed in 15.2% of 66 eyes operated on using

20 G surgery compared to 8.6% of 35 eyes operated on using 23 G TSV for PDR. In a study evaluating the effectiveness of high-speed (5,000 cpm) 25 G PPV in the treatment of various vitreoretinal diseases, no retinal break was reported in six eyes operated for PDR.[13] In this study, we observed iatrogenic retinal break in 15% of eyes. We believe that uncut vitreous fibers can be prevented with higher cut rates, and as a result of this, aspirated tissue volume is decreased, with lesser fluctuation and easier vitreous cleaning (shaving) close to the mobile peripheral retina. All these result in less retinal traction and breaks.

Measuring the traction force on retina during vitrectomy has always been an issue so far. Teixeira et al[51,52] used porcine eyes to show this challenge and found that retinal traction is decreased with higher cut rates and increased with proximity to the retina, and reported that for each 500 cpm increase, a decrease of 2.51 dynes of traction force was observed on the retina.

Combining preoperative IVB with surgery is a good alternative to treat PDR. Mainly, two surgical rules determine the efficacy of therapy: eliminating intraoperative complications by pharmacologic involution of retinal neovascularization and simplifying the segmentation and delamination of membranes with fewer instrument exchanges, and minimizing intraoperative bleeding.[34] Although the effect of bevacizumab is difficult to evaluate objectively, recent studies of off-label IVB injections have reported the efficacy and safety of bevacizumab for intraocular bleeding and postoperative complications in vitrectomy.[53–56] In this study, eleven eyes (41%) were given IVB within a week prior to surgery. Intraoperative bleeding during the removal of fibrovascular membranes was observed in almost all the cases, but most bleeding was minor and preoperative IVB.

VH is a common indication for PPV in PDR and is a relatively common postoperative complication.[57] Prior studies have found different rates ranging from 10.2% to 63%. Park et al[2] reported VH rate of 11.4% for the eyes with PDR treated with 23 G TSV. In this study, VH developed in five of the 27 eyes (18%). One of these patients had received IVB. Several studies have found decreased VH rates with preoperative or intraoperative IVB in PPV for PDR.[58,59] In addition, IVB has been shown to hasten the clearance of postoperative VH.[60] On the other side, some studies claim that the use of preoperative IVB does not help to reduce postoperative VH, but intraoperative IVB application reduces VH risk significantly.[61] Besides, there have also been reports that preoperative IVB may exacerbate tractional retinal detachment.[62]

Cataract formation and vitreoretinal diseases usually occur together, especially in the elderly population, and the intraoperative visualization of the posterior segment during vitrectomy can be affected by lens opacity. In addition, if the cataract is not significant at the time of vitrectomy, vitreoretinal surgery and usage of an intraocular tamponade can accelerate the process of cataract formation.[63] Combined vitreoretinal and cataract surgery has numerous advantages, including less risk of anesthesia, better visualization of intraoperative retina, performing sufficient peripheral vitrectomy, improving early visual rehabilitation, and the necessity of only one operation, which may reduce patient discomfort and decrease the costs.[64] However, simultaneous cataract and vitreoretinal surgery has potential disadvantages, including difficulty in visualizing the capsulorhexis due to an absent or reduced red reflex in eyes with PDR and a number of other potential complications.[63–65]

Postoperative hypotony, with or without an accompanying wound leak, is a well-known complication of sutureless vitrectomy. Studies showed that postoperative hypotony (defined as <6) is between 2% and 10%.[9–12,66] In our cases, we found no hypotony even with total vitrectomy, including vitreous base, known as one of the major risk factors for sclerotomy leakage. Factors that can explain this result are as follows: 1) all cases received endotamponades (silicone oil, gas, and air); and 2) two-step entry technique and aggressive suture placement was performed when required. Endophthalmitis did not develop in any case during follow-up.

This study had several limitations: its retrospective and noncomparative nature, a small interventional case series without a control group, a short follow-up time without surgery time evaluation, and without videos and photos. It is the best way to compare cases by their severity and compare the tamponades in each. As the focal and broad fibrovascular membrane groups were small, we did not compare the anatomic and functional results of the groups. Moreover, it is a much more effective way to compare the efficacy and results of new equipments with those of old ones, as well as the effectiveness of different tamponades in similar cases.

Conclusion

In conclusion, segmentation and removal of fibrovascular membranes with 23 G TSV using high-speed vitrectomy (5,000 cpm) was observed to be safe and effective in the management of severe DFVP. Further randomized, prospective, and comparative studies, including a larger

number of patients with a longer follow-up time, are required to come to a more reliable conclusion.

Disclosure

The authors report no conflicts of interest in this work.

References

1. Newman DK. Surgical management of the late complications of proliferative diabetic retinopathy. *Eye (London)*. 2010;24(3):441–449.
2. Park DH, Shin JP, Kim SY. Comparison of clinical outcomes between 23-gauge and 20-gauge vitrectomy in patients with proliferative diabetic retinopathy. *Retina*. 2010;30(10):1662–1670.
3. Chen JC. Sutureless pars plana vitrectomy through self-sealing sclerotomies. *Arch Ophthalmol*. 1996;114(10):1273–1275.
4. Fujii GY, De Juan E Jr, Humayun MS, et al. A new 25-gauge instrument system for transconjunctival sutureless vitrectomy surgery. *Ophthalmology*. 2002;109(10):1807–1812.
5. Kellner L, Wimpissinger B, Stolba U, Brannath W, Binder S. 25-gauge vs 20-gauge system for pars plana vitrectomy: a prospective randomized clinical trial. *Br J Ophthalmol*. 2007;91(7):945–948.
6. Khanduja S, Kakkar A, Majumdar S, Vohra R, Garg S. Small gauge vitrectomy: recent update. *Oman J Ophthalmol*. 2013;6(1):3–11.
7. Neuhann IM, Hilgers RD, Bartz-Schmidt KU. Intraoperative retinal break formation in 23-/25-gauge vitrectomy versus 20-gauge vitrectomy. *Ophthalmologica*. 2013;229(1):50–53.
8. Eckardt C. Transconjunctival sutureless 23-gauge vitrectomy. *Retina*. 2005;25(2):208–211.
9. Duval R, Hui JM, Rezaei KA. Rate of sclerotomy suturing in 23-gauge primary vitrectomy. *Retina*. 2014;34(4):679–683.
10. Gupta OP, Ho AC, Kaiser PK, et al. Short-term outcomes of 23-gauge pars plana vitrectomy. *Am J Ophthalmol*. 2008;146(2):193–197.
11. Lott MN, Manning MH, Singh J, Zhang H, Singh H, Marcus DM. 23-gauge vitrectomy in 100 eyes: short-term visual outcomes and complications. *Retina*. 2008;28(9):1193–1200.
12. Tewari A, Shah GK, Fang A. Visual outcomes with 23-gauge transconjunctival sutureless vitrectomy. *Retina*. 2008;28(2):258–262.
13. Rizzo S, Ebert-Genovesi F, Belting C. Comparative study between a standard 25-gauge vitrectomy system and a new ultrahigh-speed 25-gauge system with duty cycle control in the treatment of various vitreoretinal diseases. *Retina*. 2011;31(10):2007–2013.
14. Fang SY, DeBoer CM, Humayun MS. Performance analysis of new generation vitreous cutters. *Graefes Arch Clin Exp Ophthalmol*. 2008;246(1):61–67.
15. Hubschman JP, Gupta A, Bourla DH, Culjat M, Yu F, Schwartz SD. 20-, 23-, and 25-gauge vitreous cutter performance and characteristics evaluation. *Retina*. 2008;28(2):249–257.
16. Magalhaes O Jr, Chong L, DeBoer C, et al. Vitreous dynamics: vitreous flow analysis in 20-, 23-, and 25-gauge cutters. *Retina*. 2008;28(2):236–241.
17. Sato T, Kusaka S, Oshima Y, Fujikado T. Analyses of cutting and aspirating properties of vitreous cutters with high speed camera. *Retina*. 2008;28(5):749–754.
18. El Annan J, Carvounis PE. Current management of vitreous hemorrhage due to proliferative diabetic retinopathy. *Int Ophthalmol Clin*. 2014;54(2):141–153.
19. Hsu YR, Yang CM, Yeh PT. Clinical and histological features of epiretinal membrane after diabetic vitrectomy. *Graefes Arch Clin Exp Ophthalmol*. 2014;252(3):401–410.
20. Benhmidoune L, McHachi A, Boukhrissa M, et al. Use of bevacizumab in the treatment of complicated proliferative diabetic retinopathy. *J Fr Ophthalmol*. 2013;36(9):758–763.
21. Gupta V, Arevalo JF. Surgical management of diabetic retinopathy. *Middle East Afr J Ophthalmol*. 2013;20(4):283–292.
22. Abu El-Asrar AM. Evolving strategies in the management of diabetic retinopathy. *Middle East Afr J Ophthalmol*. 2013;20(4):273–282.
23. Shi L, Huang YF. Postvitrectomy diabetic vitreous hemorrhage in proliferative diabetic retinopathy. *J Res Med Sci*. 2012;17(9):865–871.
24. Khuthalia MK, Hsu J, Chiang A, et al. Postoperative vitreous hemorrhage after diabetic 23-gauge pars plana vitrectomy. *Am J Ophthalmol*. 2013;155(4):757–763.
25. Zenoni S, Comi N, Fontana P. Individualised treatment of proliferative diabetic retinopathy: optimal surgical timing improves long-term outcomes. *EPMA J*. 2010;1(1):78–81.
26. Arumi JG, Boixadera A, Martinez-Castillo V, Corcostequi B. Transconjunctival sutureless 23-gauge vitrectomy for diabetic retinopathy. Review. *Curr Diabetes Rev*. 2009;5(1):63–66.
27. Horozoglu F, Yanyali A, Macin A, Nohutcu AF, Keskinbora KH. 23-gauge transconjunctival sutureless vitrectomy for retained lens fragments after complicated cataract surgery. *Retina*. 2012;32(3):493–498.
28. Okamoto F, Okamoto C, Sakata N, et al. Changes in corneal topography after 25-gauge transconjunctival sutureless vitrectomy versus after 20-gauge standard vitrectomy. *Ophthalmology*. 2007;114(12):2138–2141.
29. Cha DM, Woo SJ, Park KH, Chung H. Intraoperative iatrogenic peripheral retinal break in 23-gauge transconjunctival sutureless vitrectomy versus 20-gauge conventional vitrectomy. *Graefes Arch Clin Exp Ophthalmol*. 2013;251(6):1469–1474.
30. Rizzo S, Genovesi-Ebert F, Murri S, et al. 25-gauge sutureless vitrectomy and standard 20-gauge pars plana vitrectomy in idiopathic epiretinal membrane surgery: a comparative pilot study. *Graefes Arch Clin Exp Ophtalmol*. 2006;244:472–479.
31. Shinoda H, Shinoda K, Satofuka S, et al. Visual recovery after vitrectomy for macular hole using 25-gauge instruments. *Acta Ophthalmol*. 2008;86(2):151–155.
32. Mason JO 3rd, Colagross CT, Vail R. Diabetic vitrectomy: risks, prognosis, future trends. *Curr Opin Ophthalmol*. 2006;17:281–285.
33. Shah CP, Ho AC, Regillo CD, Fineman MS, Vander JF, Brown GC. Short-term outcomes of 25-gauge virectomy with silicone oil for repair of complicated retinal detachment. *Retina*. 2008;28(5):723–728.
34. Oshima Y, Shima C, Wakabayashi T, et al. Microincision vitrectomy surgery and intravitreal bevacizumab as a surgical adjunct to treat diabetic traction retinal detachment. *Ophthalmology*. 2009;116(5):927–938.
35. Sandali O, El Sanharawi M, Lecuen N, et al. 25-, 23-, and 20-gauge vitrectomy in epiretinal membrane surgery: a comparative study of 553 cases. *Graefes Arch Clin Exp Ophthalmol*. 2011;249(12):1811–1819.
36. Magalhães O Jr, Maia M, Rodrigues EB, et al. Perspective on fluid and solid dynamics in different pars plana vitrectomy systems. *Am J Ophthalmol*. 2011;151(3):401–405.
37. Diniz B, Ribeiro RM, Fernandes RB, et al. Fluidics in a dual pneumatic ultra high-speed vitreous cutter system. *Ophthalmologica*. 2013;229(1):15–20.
38. Matsuoka N, Teixeira A, Lue JC, et al. Performance analysis of Millenium vitreous enhancer system. *Ophthalmic Surg Lasers Imaging*. 2011;42(2):162–167.
39. Narayanan R, Tibra N, Mathai A, Chhablani J, Kuppermann BD. Sutureless 23-gauge versus 20-gauge vitrectomy with silicone oil injection in rhegmatogenous retinal detachment. *Retina*. 2012;32(5):1013–1016.
40. Oliveira LB, Reis PA. Silicone oil tamponade in 23-gauge transconjunctival sutureless vitrectomy. *Retina*. 2007;27(8):1054–1058.
41. Altan T, Acar N, Kapran Z, Unver YB, Ozdogan S. Transconjunctival 25-gauge sutureless vitrectomy and silicone oil injection in diabetic tractional retinal detachment. *Retina*. 2008;28(9):1201–1206.
42. Park KH, Woo SJ, Hwang JM, Kim JH, Yu YS, Chung H. Short-term outcome of bimanual 23-gauge transconjunctival sutureless vitrectomy for patients with complicated vitreoretinopathies. *Ophthalmic Surg Lasers Imaging*. 2010;41(2):207–214.
43. Gupta B, Wong R, Sivaprasad S, Williamson TH. Surgical and visual outcome following 20-gauge vitrectomy in proliferative diabetic retinopathy over a 10-year period, evidence for change in practice. *Eye*. 2012;26(4):576–582.

44. Ozone D, Hirano Y, Ueda J, Yasukawa T, Yoshida M, Ogura Y. Outcomes and complications of 25-gauge transconjunctival sutureless vitrectomy for proliferative diabetic retinopathy. *Ophthalmologica*. 2011;226(2):76–80.
45. Yeh PT, Yang CM, Yang CH. Distribution, reabsorption, and complications of preretinal blood under silicone oil after vitrectomy for severe proliferative diabetic retinopathy. *Eye*. 2012;26(4):601–608.
46. Yorston D, Wickham L, Benson S, Bunce C, Sheard R, Charteris D. Predictive clinical features and outcomes of vitrectomy for proliferative diabetic retinopathy. *Br J Ophthalmol*. 2008;92(3):365–368.
47. Canan H, Sizmaz S, Altan-Yaycioğlu R. Surgical results of combined pars plana virectomy and phacoemulsification for vitreous hemorrhage in PDR. *Clin Ophthalmol*. 2013;7:1597–1601.
48. Ramkissoon YD, Aslam SA, Shah SP, Wong SC, Sullivan PM. Risk of iatrogenic peripheral retinal breaks in 20-G pars plana vitrectomy. *Ophthalmology*. 2010;117(9):1825–1830.
49. Kamura Y, Sato Y, Deguchi Y, Yagi F. Iatrogenic retinal breaks during 20-gauge vitrectomy for proliferative diabetic retinopathy. *Clin Ophthalmol*. 2013;7:29–33.
50. Issa SA, Connor A, Habib M, Steel DH. Comparison of retinal breaks observed during 23 gauge transconjunctival vitrectomy versus conventional 20 gauge surgery for proliferative diabetic retinopathy. *Clin Ophthalmol*. 2011;5:109–114.
51. Teixeira A, Chong LP, Matsuoka N, et al. Vitreoretinal traction created by conventional cutters during vitrectomy. *Ophthalmology*. 2010; 117(7):1387–1392.
52. Teixeira A, Chong LP, Matsuoka N, et al. Novel method to quantify traction in a vitrectomy procedure. *Br J Ophthalmol*. 2010;94(9): 1226–1229.
53. Zhang ZH, Liu HY, Hernandez-Da Mota SE, et al. Vitrectomy with or without preoperative intravitreal bevacizumab for proliferative diabetic retinopathy: a meta-analysis of randomized controlled trials. *Am J Ophthalmol*. 2013;156(1):106–115.
54. Yang CS, Hung KC, Huang YM, Hsu WM. Intravitreal bevacizumab (Avastin) and panretinal photocoagulation in the treatment of high-risk proliferative diabetic retinopathy. *J Ocul Pharmacol Ther*. 2013; 29(6):550–555.
55. Ushida H, Kachi S, Asami T, Ishikawa K, Kondo M, Terasaki H. Influence of preoperative intravitreal bevacizumab on visual function in eyes with proliferative diabetic retinopathy. *Ophthalmic Res*. 2013;49(1): 30–36.
56. Rizzo S, Genovesi-Ebert F, Di Bartolo E, Vento A, Miniaci S, Williams G. Injection of intravitreal bevacizumab (Avastin) as a preoperative adjunct before vitrectomy surgery in the treatment of proliferative diabetic retinopathy. *Graefes Arch Clin Exp Ophthalmol*. 2008;246(6):837–842.
57. Schoenberger SD, Miller DM, Riemann CD, et al. Outcomes of 25-gauge pars plana vitrectomy in the surgical management of proliferative diabetic retinopathy. *Ophthalmic Surg Lasers Imaging*. 2011; 42(6):474–480.
58. Ahmedieh H, Shoeibi N, Entezari M, Monshizadeh R. Intravitreal bevacizumab for prevention of early postvitrectomy hemorrhage in diabetic patients: a randomized clinical trial. *Ophthalmology*. 2009; 116(10):1943–1948.
59. Yeung L, Liu L, Wu WC, et al. Reducing the incidence of early postoperative vitreous hemorrhage by preoperative intravitreal bevacizumab in vitrectomy for tractional retinal detachment. *Acta Ophthalmol*. 2010; 88(6):635–640.
60. Yang CM, Yeh PT, Yang CH, Chen MS. Bevacizumab pretreatment and long-acting gas infusion on vitreous clear-up after diabetic vitrectomy. *Am J Ophthalmol*. 2008;146(2):211–217.
61. Ahn J, Woo SJ, Chung H, Park KH. The effect of adjunctive intravitreal bevacizumab for preventing postvitrectomy hemorrhage in proliferative diabetic retinopathy. *Ophthalmology*. 2011;118(11):2218–2226.
62. Jonas JB, Schmidbauer M, Rensch F. Progression of tractional retinal detachment following intravitreal bevacizumab. *Acta Ophthalmol*. 2009;87(5):571–572.
63. Canan H, Sizmaz S, Altan-Yaycioğlu R. Surgical results of combined pars plana vitrectomy and phacoemulsification for vitreous hemorrhage in PDR. *Clin Ophthalmol*. 2013;7:1597–1601.
64. Berrod JP, Hubert I. Combined phacoemulsification and pars plana vitrectomy. *J Fr Ophthalmol*. 2012;35(7):561–565.
65. Hütz WW, Hoffmann P, Hengerer F. Fifty consecutive cases of transconjunctival sutureless 23-gauge vitrectomy combined with phacoemulsification and IOL implantation. *Ophthalmic Surg Lasers Imaging*. 2011;42(6):481–486.
66. Hikichi T, Matsumoto N, Ohtsuka H, et al. Comparison of one-year outcomes between 23- and 20-gauge vitrectomy for preretinal membrane. *Am J Ophthalmol*. 2009;147(4):639–643.