Original Article

Influence of orientation of the external linear incision created by the 25-gauge trocar and related factors on sclerotomy closure: A clinical and optical coherence tomographic study

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Purpose: To assess the influence of orientation of the external linear incision created by the trocar and related factors on sclerotomy closure in 25-gauge (25G) transconjunctival vitreous surgery (TVS). **Methods:** A total of 46 eyes of 46 patients who underwent 25G TVS (23 circumferential incisions and 23 radial incisions) were studied. Clinical and anterior segment optical coherence tomography (AS-OCT)-based comparison of self-sealed and sutured sclerotomies was done. The influence of age, ocular surgeries and injections, axial length, cannula type, sclerotomy quadrant, surgery duration, vitreous base excision, and tamponade on suture rates was analyzed. **Results:** Of the 46 eyes, 23 eyes required suturing [circumferential: 17 (74%) and radial: 6 (26%); $P = 0.003$]. A significantly lesser proportion of superonasal quadrant and inferotemporal quadrant sclerotomies needed suturing [9 (24%) and 12 (27%)] when compared with superotemporal quadrant [17 (37%)]. Sclerotomies to the left of the surgeon and the infusion port required significantly lesser suturing [10 (25%) and 13 (28%), respectively] when compared with that of surgeon's right [15 (35%)]. Suturing was significantly lesser when gas or oil tamponade was used [5 (36%) and 2 (20%), respectively] when compared with no tamponade [16 (73%)]. In eyes without tamponade, suturing was lesser with radial sclerotomies ($P = 0.003$). The odds of having an open sclerotomy tract on AS-OCT were ≥5 when circumferential sclerotomies were used. **Conclusion:** Self-sealing was more common with radial external incisions. Tamponade was associated with less suturing. Superotemporal sclerotomies and sclerotomies toward the surgeon's dominant hand were often sutured. In this cohort, other factors did not influence sclerotomy closure.

Key words: 25-Gauge vitreous surgery, optical coherence tomography, scleral suturing, sclerotomy

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The introduction of 25-gauge (25G) transconjunctival vitreous surgery (TVS) by Fujii *et al*. in 2002 caused a paradigm shift in the way vitreoretinal surgery is performed.[1] The central idea of using smaller 25G systems was the ability of sclerotomy wound thus created to seal without the use of sutures. Nevertheless, the use of sutures is often required to avoid wound leak and hypotony in the postoperative period.[2] Vertical entry into the eye was replaced by the use of oblique incisions to promote self-sealing.[3,4] Multiple methods of sclerotomy creation have been described to take advantage of scleral stromal thickness.[5-7] In 25G TVS, surgeons today prefer a single plane oblique sclerotomy running parallel to the limbus along the pars plana.[7,8] However, the influence of orientation of the linear external incision created by the trocar on sclerotomy closure has not been discussed.

We therefore compared the suture rates and sclerotomy architecture with anterior segment optical coherence tomography (AS-OCT) in eyes that had circumferentially and radially oriented external incisions in 25G TVS. Besides the orientation of incisions, we also analyzed related clinical and surgical parameters that may influence suturing in 25G surgery.

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Methods

Subjects

A retrospective review of case records of patients who underwent 25G TVS by a single surgeon (MVG) in at a tertiary eye care institute in India from March 2017 to May 2017 was conducted. The Institutional Review Board clearance and Ethical Committee approval were obtained. The study adhered to the tenants of the Declaration of Helsinki. Among the 68 records of 25G TVS reviewed, we excluded the eyes that underwent conjunctival peritomy (encirclage or segmental scleral buckle), lamellar scleral dissection (small incision cataract surgery), or had more than three sclerotomies (scleral fixated intraocular lens) along with retinal surgery. Imaging studies have shown that sclerotomies heal well by 6–8 weeks.[9,10] Therefore, we only included eyes that had no scleral incisions in the preceding 3 months before the present 25G TVS.

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Clinical investigations and surgery

Preoperatively, a retina specialist evaluated all patients. Ocular history such as past cataract surgery, retinal surgery, panretinal photocoagulation (PRP), intravitreal anti-vascular endothelial growth factor (VEGF) injection, and intravitreal antibiotic injection was recorded. Axial length in both eyes was measured by optical biometry (IOLMaster 700; Carl Zeiss, Oberkochen, Germany), and intraocular pressure (IOP) presurgery, on postsurgery day 1, and postsurgery week 1 were recorded with non-contact tonometry (CT-80; Topcon, Tokyo, Japan). Indications for surgery were rhegmatogenous retinal detachment, macular holes, diabetic tractional retinal detachment, vitreous hemorrhage, endophthalmitis, and silicone oil removal. A single surgeon (MVG) performed all surgeries using the same surgical technique for sclerotomy creation and closure. Either of the two vitrectomy systems and the corresponding 25G trocar cannulas were used (CONSTELLATION® Vision System; Alcon, TX, USA or EVA; D.O.R.C., Zuidland, Netherlands). Sclerotomies were made by displacing the conjunctiva with forceps and using an oblique, single plane entry 3–3.5 mm from the limbus and tangential to it directed along the pars plana with an angle of 20°–30° to the ocular surface [Fig. 1]. The trocar was held in a manner such that the linear external entry wound created by the trocar is either circumferential or radial in relation to limbus. Standard 3 ports in the inferotemporal quadrant (ITQ), superotemporal quadrant (STQ), and superonasal quadrant (SNQ) were used for all cases except silicone oil removal where ITQ and STQ ports were made. At the conclusion of surgery, the cannulas were plugged and removed in the same direction of entry with continuous compression on sclerotomy site using a cotton tipped applicator. Massage was done with a blunt instrument to facilitate sclerotomy closure. Thereafter, the presence of wound leak and hypotony after clamping the infusion cannula with or without formation of a conjunctival bleb warranted sclerotomy suturing. Each port was sequentially dealt with and sutures were placed if necessary before proceeding to cannula removal at the next port. IOP by non-contact tonometry at first postoperative day and at the first week was taken for analysis. None of the patients needed resurgery to close any sclerotomy after primary surgery.

The sclerotomy morphology was studied with the AS module of Spectralis OCT (Heidelberg Engineering, Heidelberg, Germany) 1 week after surgery. Scleral mode image acquisition with enhanced depth imaging (EDI) that uses 41 horizontal line scans with 69 µm separation between two scans in a 15° × 5° grid was used. The horizontal raster scan was manually adjusted to cover sclerotomy in each quadrant. The status of sclerotomy was graded based on four parameters: the outer lip, the sclerotomy tract, the inner lip, and vitreous incarceration at the inner lip [Fig. 2].

Statistical analysis

Descriptive analyses of demographic and surgical parameters were performed. Circumferential and radial sclerotomies were tabulated separately. Thereafter, eyes with self-sealed and sutured sclerotomies were analyzed. Differences between groups were evaluated using Chi-square for categorical data (Fisher's exact test) and independent samples *t*-test

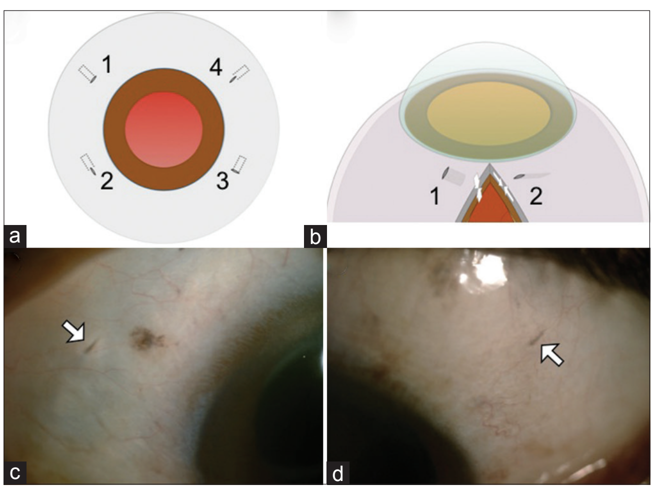

Figure 1: Sclerotomies in 25-gauge vitreous surgery. A sclerotomy by a 25-gauge trocar has an external linear entry wound that is either circumferential [1 and 2 (a); arrow (c)] or radial [3 and 4 (a); arrow (d)) to the limbus. The intrascleral path may be parallel to [2 and 3 (a)] or perpendicular to [1 and 4 (a)] the limbus. Forces acting perpendicularly across the sclera will close a sclerotomy with a radial external incision [arrows, 1 (b)], whereas forces acting tangentially along the sclera will close a sclerotomy with a circumferential incision [arrows, 2 (b)]

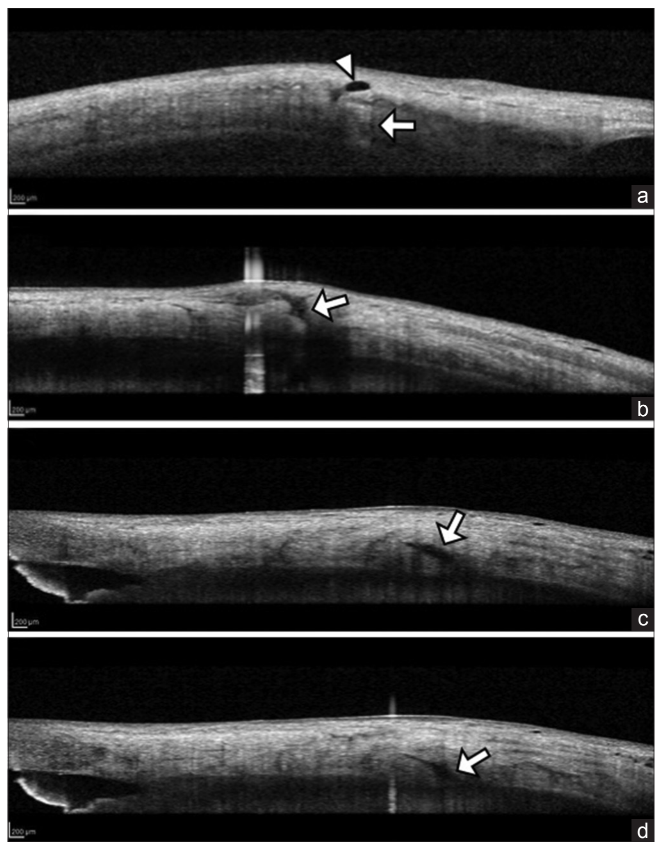

Figure 2: Anterior segment optical coherence tomography of the sclerotomy 1 week after surgery. A well-opposed outer lip and tract of the sclerotomy wound [(a), arrow]. A conjunctival cyst is seen overlying the outer lip of the sclerotomy [(a), arrowhead]. An open outer lip and tract of the sclerotomy wound [(b), arrow]. A hyporeflective space that extends from scleral stroma to inner scleral boundary denotes an open tract and inner lip [(c), arrow]. A wedge-shaped hyporeflective region at the inner scleral boundary indicates an open inner lip of the sclerotomy [(d), arrow]

(Mann–Whitney *U* test) for continuous variables. Regression analysis was performed to eliminate confounders and to correct for age. A statistically significant difference was made when *P* value was less than 0.05. All these statistical analyses were performed with SPSS 23 (SPSS Inc., Chicago, IL, USA).

Results

The demographic parameters, surgical indications, preoperative IOP, and IOP on postsurgery day 1 and day 7 along with the number of sutured eyes and sclerotomies are tabulated [Table 1]. Of the 46 eyes, 23 eyes required suturing [circumferential: 17 (74%) and radial: 6 (26%); *P* = 0.003]. Likewise, more circumferential sclerotomies needed suturing than radial sclerotomies [28 (45%) vs 10 (15%); *P* = 0.002]. There was no difference in the duration of surgery between eyes that had circumferential and radial external incisions.

On comparing the clinical parameters between eyes that had self-sealed sclerotomies and those that required suturing, there was no significant difference between the groups [Table 2]. When analyzing the surgical variables, the presence of valves on the cannulas or the brand of trocar did not make any difference to the suturing rates [Table 2]. On comparing the quadrants, a significantly lesser proportion of SNQ [9 (24%); *P* = 0.001] and ITQ sclerotomies needed suturing [2 (27%); *P* = 0.002] when compared with STQ [17 (37%); *P* = 0.07] Likewise, the proportion of sclerotomies to the left of the surgeon [10 (25%); *P* = 0.002] and the infusion port sclerotomies [13 (28%); *P* = 0.003] that required suturing was significantly lesser when compared with that of surgeon's right hand [15 (35%); *P* = 0.05]. Suture placement was significantly lesser when gas or oil was used as tamponade [5 (36%) and 2 (20%), respectively; *P* = 0.007] when compared with no tamponade [16 (73%)].

On analyzing sclerotomies with AS-OCT 1 week after surgery, 72 (56%) ports were not gradable because of suturing, hemorrhage, or chemosis [Table 3]. Irrespective of the quadrant studied, the odds of having an open sclerotomy tract were ≥5 when circumferential sclerotomies were used. Statistically significant difference between open and closed tracts was seen in SNQ (*P* = 0.01).

Table 1: Demographic and surgical parameters of eyes that underwent 25G transconjunctival vitreous surgery with circumferential and radial sclerotomies

	n	Circumferential sclerotomy	Radial sclerotomy
Age (years), mean (range; SD)	46	52 (9-75; 16.8)	55.9 (33-78; 11.8)
Males (%)	34	17 (74)	17 (74)
Right eye (%)	28	13 (46)	15 (54)
Duration of surgery (min), mean (range; SD)	46	38.74 (15-76; 17.59)	45.43 (15-77; 18.66)
Intraocular pressure (mmHg), mean (range; SD)			
Presurgery	46	14.9 (10-31; 4.52)	14 (7-30; 5.11)
Postsurgery day 1	46	15.3 (4-27; 6.04)	13.9 (5-29; 5.16)
Postsurgery day 7	46	15.1 (4-42; 7.96)	15.4 (8-43; 8.11)
Number of eyes sutured (%)	23	17 (74)	6 (26)**
Number of sclerotomies (%)		62 (48)	67 (52)
Number of sclerotomies sutured (%)		28 (45)	10 (15)**

n: Number of eyes, SD: Standard deviation, ***P*<0.01

Discussion

When compared with cornea, collagen in the sclera is laid down in an irregular and intermingling pattern.[11] Scanning electron microscopy, transmission electron microscopy, and atomic force microscopy have shown a reticular or rhombic arrangement of collagen framework in the superficial and deep sclera.[11,12] Therefore, it is imperative to study the surgical outcomes with different sclerotomy architectures in 25G TVS and assess which did not require suture placement. The existing literature on the subject of direction of sclerotomy wounds is based on the assumption that scleral fibers are arranged in a regular concentric pattern parallel to the limbus and that "separation" of fibers by the incision rather than "cutting" the fibers would lead to earlier wound closure.[6,7]

In creating an oblique sclerotomy for 25G TVS, the surgeon may orient the external incision either circumferential or radial to the limbus and the direction of the intrascleral path can be either parallel or perpendicular to the limbus.[6,7] The surgeon thus has four potential combinations to choose from when making an oblique sclerotomy [Fig. 1]. With respect to external incision, both the radial and circumferential incisions are commonly used. On the other hand, the direction of intrascleral tunnels is usually parallel to the limbus [Fig. 1a (2 and 3)] since perpendicularly directed sclerotomies [Fig. 1a (1 and 4)], posteriorly from the limbus or anteriorly toward the limbus, may cause inadvertent retinal or lenticular damage.[7] With respect to the number of planes, a single plane, long and oblique incision is preferred over bi-planar incisions that may cause damage to internal scleral lip and lead to leaky sclerotomies.[7,8] While removing sclerotomy cannulas, earlier studies recommended the removal over a non-hollow bore instrument to avoid vitreous prolapse.[13] However, recent studies have shown that there is greater frequency of leakage and suturing.[14,15] Hence, we removed the cannulas in a routine manner after plugging them.

Influence of age, past cataract or vitreoretinal surgery, axial length, and vitreous base shaving on sclerotomy closure in small gauge vitreous surgery has been evaluated in many studies with varied results.[16-21] In our cohort of patients, none of these factors influenced suture rates in 25G TVS. Since the choroid forms a part of the eye wall, we also analyzed the effect of PRP and anti-VEGF agents on sclerotomy wound closure and found no difference in suture rates.

We compared the suture rates of sclerotomies created by two commonly used commercially available 25G vitrectomy systems (Alcon and Dorc) and found no significant difference. Introduction of valved cannulas has reduced fluid egress and incarceration of vitreous.[13] However, in our study, the presence of valves on the cannulas did not increase the self-sealing nature of sclerotomies.

Table 2: Comparison of clinical and surgical parameters of eyes that underwent 25G transconjunctival vitreous surgery and had self-sealed or sutured sclerotomies

	n	Self-sealed sclerotomies	Sutured sclerotomies
Demographic parameters			
Age (years), mean (range; SD)	46	56.3 (17-78; 13.2)	51 (9-75; 15.7)
Males (%)	34	14 (61)	20 (87)
Ocular parameters			
Past cataract surgery (%)	22	13 (57)	9 (39)
Past VR surgery (%)	14	4 (17)	10 (43)
Past PRP (%)	11	7 (30)	4 (17)
Past anti-VEGF (%)	7	3 (13)	4 (17)
Past intravitreal antibiotic (%)	4	2 (9)	2 (9)
Axial length (mm) (range; SD)			
Operated eye	46	23.15 (21.49-26.37; 1.28)	23.38 (22.63-25.33; 0.75)
Contralateral eye	46	23.11 (21.52-26.60; 1.28)	23.32 (20.99-25.08; 0.90)
Surgery parameters, number of eyes (%)			
Circumferential sclerotomy	23	6 (26)	17 (74)**
Radial sclerotomy	23	17 (74)	6 (26)
Alcon trocar	28	14 (61)	14 (61)
Dorc trocar	18	9 (39)	9 (39)
Valved cannula	23	12 (52)	11 (48)
Nonvalved cannula	23	11 (48)	12 (52)
Surgery parameters, number of sclerotomies (%)			
STQ	46	29 (63)	17 (37)
SNQ	38	29 (76)	9 (24)**
ITQ	45	33 (73)	12 (27)**
Surgeon's right	43	28 (65)	15 (35)
Surgeon's left	40	30 (75)	10 (25)**
Infusion port	46	33 (72)	13 (28)**
Duration of surgery (min), mean (range; SD)	46	45.1 (15-77; 18.5)	39.4 (15-76; 17.9)
Vitreous base shaved (%)	16	8 (35)	8 (35)
Tamponade (%)	24	17 (70)	7 (30)**
Gas (%)	14	9 (64)	5 (36)
Silicone oil (%)	10	8 (80)	2 (20)**
Circumferential: radial		6:11	5:2
No tamponade (%)	22	6 (27)	16 (73)
Circumferential: radial		0:6	12:4**

n: Number of eyes, SD: Standard deviation, VR: Vitreoretinal, PRP: Panretinal photocoagulation, VEGF: Vascular endothelial growth factor, STQ: Supertemporal quadrant, SNQ: Superonasal quadrant, ITQ: Inferotemporal quadrant, $^{**}P<0.01$

Increased surgical manipulation and repeated passage of instruments through superior sclerotomies have been related to increased suturing at these sclerotomies when compared to the relatively static infusion port.[2,18] In our study, the proportion of sutured sclerotomies in SNQ and INQ was significantly less than self-sealed sclerotomies, whereas the proportion of self-sealed and sutured sclerotomies was not statistically different in STQ. When analyzing the port sites in relation to the right-handed surgeon, we found that left-sided ports and infusion ports had proportionally lesser suturing, whereas the right-sided ports were sutured more often. During surgery, a right-handed surgeon will tend to use his right hand for most surgical maneuvers. Likewise, the STQ port, which provides more room for instrument rotation and anterior reach, will be subjected to more deformation. Hence, the findings of our study correlate with and reinforce the available evidence on the subject that intraoperative scleral deformation does increase the suture rates. On the other hand, analysis of the influence of surgery duration on sclerotomy closure has shown conflicting results.[2,3,16,18] In our cohort, when comparing the time taken for surgeries that required suturing and those that did not, we found no significant difference. This could be explained by the wide surgical indications for patients in both groups of this study.

With AS-OCT, it is demonstrated that 25G sclerotomies closed better in gas-filled eyes than fluid-filled eyes.[22] Similarly, in our study, suturing of sclerotomies was significantly lesser in gas- or oil-filled eyes. In the classical description of internal tamponade, the high interfacial tension of a gas or silicone oil bubble in water is made use of to seal the retinal break. Another explanation for closure of a retinal break with tamponade is that the mere presence of gas or oil acts as a "splint" within

Table 3: Comparison of anterior segment optical coherence tomography parameters of circumferential and radial sclerotomies in eyes that underwent 25G transconjunctival vitreous surgery

	n	Circumferential sclerotomy	Radial sclerotomy	OR
Ungradable sclerotomies (%)	72 (100)	39 (53)	33 (47)	
Sutures	38 (53)	28 (72)	10 (30)	
Subconjunctival hemorrhage	21 (29)	5 (13)	16 (48)	
Chemosis	13 (18)	6 (15)	7 (21)	
Gradable sclerotomies (%)	57 (100)	23 (40)	34 (60)	
STQ	21 (37)	9 (39)	12 (35)	
Open external lip	6 (29)	3 (33)	3 (25)	1.5
Open tract	5 (24)	4 (44)	1 (8)	8.8†
Open internal lip	7 (33)	4 (44)	3 (25)	0.18
Vitreous incarceration	1 (4)	1 (11)	0 (0)	2.14
SNQ	16 (28)	5 (22)	11 (32)	
Open external lip	6 (37)	2 (40)	4 (36)	1.16
Open tract	5 (31)	4 (80)	1 (9)*	40†
Open internal lip	8 (50)	3 (60)	5 (45)	0.60
Vitreous incarceration	1 (6)	1 (20)	0 (0)	3.0
ITQ	20 (35)	9 (38)	11 (32)	
Open external lip	8 (40)	5 (55)	3 (27)	1.25
Open tract	4 (20)	3 (33)	1 (9)	5†
Open internal lip	6 (75)	2 (22)	4 (36)	0.13
Vitreous incarceration	2 (10)	1 (11)	1 (9)	1.5

n: Number of sclerotomies, OR: Odds ratio, STQ: Supertemporal quadrant, SNQ: Superonasal quadrant, ITQ: Inferotemporal quadrant, **P*<0.05, †OR ≥5

the eye and prevents intraocular fluid currents that are responsible for reopening of breaks.[23] We postulate that with use of tamponading agents, the same mechanisms assist in physiological closure of sclerotomy at the pars plana region and prevent fluid egress through internal scleral opening. Of particular note, in our study eyes that did not receive either gas or oil tamponade, self-sealed sclerotomies were significantly more in those eyes that had radially oriented external incisions. This signifies the superior wound architecture of a sclerotomy that has radial external incisions.

Taban *et al.* were the first to use AS-OCT to study sclerotomy site morphology after vitrectomy.[24] Subsequently, other authors have validated the results and defined wound closure, gaping, and misalignment of sclerotomy wounds as seen on AS-OCT [Fig. 2].[2] Wound healing in 25G sclerotomies, as graded by the AS-OCT, is seen to be complete by 2 weeks to 1 month after surgery.[25] Among the gradable sclerotomies in our study, irrespective of the quadrant analyzed, the odds of having an open sclerotomy tract was found to be more than 5 in patients who had circumferential sclerotomies and a statistically significant difference was found in SNQ. Research has shown that centrifugal forces directed outward from within the eye are important for the closure of a beveled incision on the eye wall.[2] In beveled incisions, the internal lip presses against the outer lip aided by the IOP, thereby helping the closure of the wound and reducing the risk of leakage, hypotony, and infection.[3,4] This affixing of the inner and outer lip increases as the IOP increases. From the suture rates and AS-OCT features of sclerotomies in our study, it is understood that mechanical closure of the oblique scleral tunnel formed by a radially oriented MVR trocar in the early postoperative period is better than the tunnel formed by the circumferentially oriented MVR trocar. When orienting the MVR trocar radial to the limbus, the plane of the intrascleral tunnel formed lies parallel to the scleral plane. The centrifugal vectors acting inside out from within the eye aid in approximating the inner and outer lips to achieve sclerotomy closure in the early postoperative period [arrows, Fig. 1b (1)]. In contrast, the plane of a scleral tunnel obtained with a circumferentially oriented MVR trocar would lie vertical and perpendicular to the scleral plane. Only tangential forces acting along the scleral plane can effectively close such a tunnel [arrows, Fig. 1b (2)]. Therefore, it stands to reason that closure of a 25G sclerotomy is better with radial orientation of MVR trocar.

Our study was not without limitations. The small sample size, introduction of confounding factors due to the retrospective nature of the study, and absence of a "direct entry" control group are the drawbacks. A wide variety of surgeries were included. Randomization with analysis of particular retinal surgeries can give more specific data. Since we aimed to analyze only the intraoperative suture rates and early postoperative sclerotomy site architecture with AS-OCT, we have a short follow-up period for the study. Prospective randomized studies with a larger sample size and longer follow-up would help address the issues of wound remodeling in 25G sclerotomies.

Conclusion

Our study has shown that when making sclerotomies to perform 25G TVS, creation of radially oriented external incisions helps in achieving self-sealed wounds at the end of surgery. On AS-OCT, sclerotomy tract approximation at first postoperative week was also seen to be better with radial incisions. We identified that sclerotomies on the favored side of the surgeon and in STQ need suturing more often than other sclerotomies. The use of gas or oil as tamponade agents is associated with less frequent suturing. In our cohort of patients, other clinical and surgical parameters such as past cataract surgery, retinal surgery, anti-VEGF injections, PRP, intravitreal antibiotic injections, axial length of either eye, the brand of the trocar cannula system used, valved cannulas, duration of surgery, and vitreous base excision did not influence the suture rates in 25G TVS.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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