Review Article

Sutureless vitrectomy

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Sutureless vitrectomy has rapidly been accepted as an essential part of a vitreoretinal surgical setup. The size and structure of the wound along with near intact conjunctival covering makes the incision self-sealing and safe. This allows the vitrectomy instruments to be used without creating an initial limited peritomy to expose bare sclera, and obviates the need for sutures at the end of the procedure. Wound construction is the essential step in ensuring postoperative wound stability. Both one-step and two-step wound constructions have been described. Key points include an oblique, tunneled approach to ensure a valve-like effect as well as misalignment of conjunctival and scleral wounds by displacing conjunctiva during construction. Advantages include decreased operative times in certain cases and decreased postoperative inflammation, early postoperative rehabilitation, improved patient comfort, and minimal conjunctival damage. Complications are based around wound competence, hypotony, and its relationship to endophthalmitis rates. Early reports highlighted an increase in endophthalmitis though further studies are required to accurately assess the incidence. Endophthalmitis has not been reported in cases that underwent fluid/air exchange. This review focuses on techniques, benefits, complications, personal experiences, and the safety profiles of sutureless vitrectomy systems. A literature review was undertaken using 'Medline' and 'Pubmed'. Search terms included sutureless vitrectomy, 20 gauge, 23 gauge, 25 gauge, and transconjunctival and small gauge vitrectomy.

Key words: 20 gauge, 23 gauge, 25 gauge, sutureless vitrectomy, transconjunctival

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Pars plana vitrectomy as a technique has revolutionized retinal surgery since its advent and initial report by Machemer *et al*.[1] It allowed the removal of traction by an internal method, essential in retinal detachment procedures, as well as provided an active management modality for vitreous hemorrhage and opened the door for surgical intervention in a myriad of retinal pathologies.

Since that time, the evolution of vitrectomy surgery has seen experimentation and implementation of smaller surgical instruments aimed at greater functionality and minimalization of ocular trauma. The basis of a sutureless pars plana sclerotomy was to stabilize intraocular pressure (IOP) during surgery,[2] with a truly closed system, as well as reduce surgical time by removing the need for sutured wound closure. Wound and suture related complications such as leakage, irritation, and scleral pigmentary changes could also be avoided. Concerns regarding wound competence in a sutureless procedure have seen the modification of the conventional straight incision to such techniques as angled, beveled, oblique, and scleral tunnel incisions.

The aim of this paper is to briefly outline the history of pars plana vitrectomy and describe the common surgical techniques in sutureless vitrectomy. Employing a Medline and Pubmed literature search, we summarize published benefits, complications, and outcomes as well adding our own personal experiences in utilizing this technique. Search terms included sutureless vitrectomy, 23 gauge, 25 gauge, transconjunctival, and small gauge vitrectomy.

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History of Pars Plana Vitrectomy Surgery

In 1971, Machemer *et al*,[1] described the use of a 17-guage vitreous cutter, with a diameter of 1.5 mm through a 2.3 mm scleral incision. This instrument, the vitreous infusion suction cutter (VISC), consisted of an inner and outer tube. The outer tube was stationary with an opening, inside which, was the rotating opening of the inner tube with sharp edges. Suction was applied to the inner tube to draw vitreous into the openings and the rotating sharp edge would cut the material. The instrument was connected to a rheostat to alter rotation speed, an infusion system, and a syringe that allowed manual application of suction. This was utilized in an eye with vitreous hemorrhage secondary to diabetic retinopathy.

The approach was modified in 1974, with the introduction of a 20-gauge vitrector (0.9 mm diameter) by O'Malley and Heintz.[3] This was the origin of the three port, pars plana sclerotomy system that became the gold standard in vitrectomy surgery. It involved the creation of three access ports with a 1.4 mm linear sclerotomy. This was undertaken with a myringo-vitreal-retinal (MVR) blade. One port had an infusion line sewn into place, while the remaining two were utilized for introduction of a light source and a vitreous instrument such as a cutter. At the completion of the procedure, these ports were traditionally closed with an absorbable suture.

In 1996, Chen[4] described a technique for creating a self-sealing, pars plana sclerotomy. This involved an initial scleral

incision based 6 mm posterior to the limbus, creating a scleral flap that was theoretically self-sealing. Kwok *et al*,[2] described a variation on this method with an initial radial incision, still placed 3–4 mm behind the corneoscleral limbus. They used a 20-guage round body hypodermic needle rather than a MVR blade.

De Juan and Hickingbotham[5] devised and introduced a range of 25-guage instruments in 1990 for use through conventional sclerotomies. However, it was only in 2002, with the advent of the microcannulae array, that the 25-gauge transconjunctival sutureless vitrectomy (TSV) system was introduced by Fujii *et al*. This was followed by the introduction of a 23-gauge system by Eckardt in 2005.[7]

Initially, both 23- and 25-gauge systems were available with a limited gamut of intraocular instruments. However, as the techniques rapidly became widely utilized, almost all intraocular instruments have been developed and made available for sutureless vitrectomy systems.

Fluid Dynamics in Sutureless Surgery

The vitreous behaves as both a solid and a liquid; given its major constituents are water (98%) and proteins such as collagen and hyaluronic acid. Other noncollagenous proteins and glycoproteins have also been identified.[8] The increasing use of smaller gauge systems has led to the finding that there is decreased flow performance during vitreous removal in 25-gauge vitrectomy relative to standard 20-gauge vitrectomy. This may be a rate-limiting step influencing the total surgical time.

The flow rate is affected by a number of factors, one of which is the duty cycle of the cutter. The duty cycle is the percentage of time the cutter port is open relative to each cutting cycle. When the port is open, the aspiration pressure draws some vitreous into the cutter. During cutting, a chunk of vitreous is removed from the main 'block' of vitreous. As the cut rate increases, at any given flow rate, the amount of vitreous in each bite is reduced. Reducing the aspiration pressure will decrease the traction on the remaining vitreous or retina. Other factors affecting flow rate are the nature of the removed substance, variable parameters such as vacuum applied and cutting rate, drive mechanism (pneumatic or electric), blade movement (axial or rotational), and the internal diameter of the vitrector.[9]

Flow analysis was undertaken in 20-, 23-, and 25-gauge systems using porcine vitreous.[9] Analysis of the percentage of vitreous flow rate/balanced salt solution (BSS) flow rate at different aspiration and cut rates showed an ascending curve providing evidence of flow obstruction at all cut rates, in all three systems. In the 20-gauge electric system, at faster cut rates, vitreous was removed faster and had less resistance, due to smaller pieces being removed. The 25-gauge electric system also had higher vitreous flow rates at high cut rates. Assessment of the 23-gauge pneumatic system revealed decreased duty cycle and incomplete aperture opening at 1500 cpm with resultant low flow. This trend also occurred in 20- and 25-gauge pneumatic cutters, with higher absolute flow when utilizing the larger gauge systems.

Magalhaes *et al*,[10] compared infusion and extrusion volumes of three different 25-gauge systems. Average infusion rates were 167.23 μL/s with the Bausch and Lomb (Millenium™), 190.53 μL/s with Alcon (Accurus™), and 250.09 μL/s with DORC (Associate™), respectively. These values increased with raised bottle height. With the cutter off, the Bausch and Lomb and Alcon systems had lower aspiration flow rates than the DORC system. They also had a variation in aspiration flow rate of <10% between a cut rate of 0 cuts/min and 1100 cuts/min compared to >50% in the DORC system, demonstrating lower power but greater flow stability. These findings may be of benefit when considering which system is best suited to a particular surgical procedure. Increased infusion rate and aspiration power may be of benefit in order to remove posterior hyaloid or clots in young patients. The wider safe vitrectomy zone (when infusion rate is higher than aspiration rate) may be required when dissecting membranes such as in diabetic eye disease.

New generation spring return pneumatic vitreous cutters are also available with improved flow characteristics. The new generation 25-gauge cutter has 3.3 times greater vitreous flow rate than its current counterpart as well as greater vitreous flow than current generation 20-gauge cutters at high speeds. The new generation 20-gauge, 23-gauge, and 25-gauge cutters achieve high vitreous flow rates, though none exceeds the range of absolute values used currently by surgeons. The new generation cutters do, however, maintain high flow rates with increasing speed as opposed to current cutters.[11,12]

Wound Construction

The single most important step for the success of sutureless vitrectomy is the configuration and correct placement of the sclerotomy so as to achieve a self-sealing wound after removal of the cannulae at the completion of surgery. This is achieved by a) creating an oblique wound so as to ensure a valve-like effect similar to clear corneal wounds for phacoemulsification; and b) misaligning the conjunctival and scleral entry sites by displacing the conjunctiva over the scleral surface before creating the wound.

Two types of wound constructions have been described, that is, one-step and two-step incisions. One-step incision involves entry with the sharp trocar with overlying cannula on it, whereas in the two-step procedure, initial entry is first made with the sharp blade and then a cannula is inserted with the help of blunt ended trocar. The one-step incision can be made obliquely perpendicular to the scleral fibers which are arranged in concentric circles near the limbus.[13] Alternatively, Shimada *et al*,[14] describe a tunneled scleral incision which is again oblique, but parallel to the limbus. This gives the added theoretical advantage of displacing, rather than cutting the scleral fibers with a reduction in healing time on UBM analysis.[13]

Two-step incisions offer the advantage of utilizing a sharp instrument for the initial cut; thus, improving the construction of the wound. Oliveira *et al*,[15] reported the use of a 0.7 mm sapphire knife as a variation on the stiletto blade initially used by Eckardt.[7] On the other hand, they present the surgeon with a dilemma in that the misalignment of wounds referred to earlier, also creates difficulty in locating the initial entry point for trocar insertion. The two-step incision is also associated with a greater learning curve as compared to a one-step incision.

25-guage system and technique

First described by Fujii *et al*,[6] in 2002, this system utilizes a microcannula array to introduce a wide range of vitreoretinal instruments. The TSV, revolves around microcannulae with insertion trocars, an infusion cannula, and cannula plugs. The microcannula is a thin walled polyamide tube of 3.6 mm in length with an external collar which can be grasped with forceps.

Insertion is accomplished by first displacing the conjunctiva laterally by approximately 2 mm. An initially oblique, then a perpendicular tunnel is made parallel to the limbus through the conjunctiva and sclera, thus, creating a self-sealing wound.[13] This technique has been modified from the initial experiences of purely perpendicular or tunneled insertion and their reported complications.[16] The trocar, when inserted into the cannula forms a continuous bevel, can then be withdrawn. The port is then in place for insertion of the desired instrument, with plugs available if required to maintain a closed system. This system ensures misalignment between the conjunctival and scleral entry site.

The infusion cannula is composed of a 5 mm metallic tube, which fits through the microcannula array. It also has a collar to allow manipulation within the eye. The variety of instruments available for use through this system has increased since the advent of 25-guage instruments by de Juan and Hickingbotham[5] in 1990. These include vitrectomy cutters, light pipe, micro vertical scissors, extendable curved pick, tissue manipulator, aspirating pick, aspirator, laser probe, and diathermy probe.

At the completion of surgery, the microcannulae are simply removed by grasping the collar and withdrawing, with assessment of IOP and wound sites for any possible leak.

23-guage system and technique

This is a variation of the 25-guage TSV system, and was first described by Eckardt[7] in 2005. The conjunctiva is displaced laterally before an angled tunneled incision is made with a 23-guage blade creating a tunnel 0.72 mm wide. The microcannulae are then inserted through these incisions using a blunt cannula inserter. The instruments with their associated greater diameter are inherently stiffer and more closely resemble standard 20-guage instruments than the 25-guage system. This may offer surgeons to be more familiar with 20-guage vitrectomy, a smoother transition and shorter learning curve. The slight increase in instrument gauge results in a higher absolute flow rate in comparison to a 25-gauge system. Another benefit noted is the placement of the cutter opening nearer to the end of the probe, which allows a closer vitreous shave. As mentioned earlier, the 23-guage system is also available using a one-step incision as well (DORC and Alcon 23G system).

20-guage system and technique

A variation on the standard 20-gauge vitrectomy has been described by Gotzaridis[17] with the use of conjunctival diathermy rather than peritomy prior to port creation. This technique aims to reduce hemorrhage and surgical time by utilizing an oblique, then perpendicular sclerotomy to create a self-sealing, sutureless wound with overlying conjunctiva, similar to the previously described 23-guage and 25-guage systems. However, it does not utilize cannulae in the port sites.

A 20-guage MVR blade is used with ports large enough to accommodate standard vitreoretinal instruments. In order to maintain the sutureless nature of the procedure, it is advisable to avoid unnecessary instrument exchange which could enlarge the ports.

In a case series of 84 eyes that underwent this technique,[17] three patients (3.5%) had hypotony at day one which normalized at day four postoperatively. Two patients had bleb formation and the rest had minor leakage with a flat conjunctiva. There were no differences found in regards to visual acuity, IOP, or inflammation; but this technique was found to offer shorter operative times. Review at two months post surgery revealed the conjunctiva was freely mobile with normal appearance of its vasculature.

More recently, Lafeta *et al*,[18] described a 20-gauge trocar system and technique. It utilizes the principles of the 23/25-gauge systems with trocars for instrument access and a separate infusion trocar. The trocars contain disposable valves, and thus, do not require plugs to maintain a closed system. They are inserted through tunneled wounds which can be left sutureless at the completion of surgery. Benefits of this array include the ability to utilize familiar vitreoretinal instruments and standard flow rates, decreased cost as compared to the smaller gauge systems, as well as the ability to undertake close peripheral vitreous shave.

Benefits

The benefits of sutureless vitrectomy, regardless of the instrument gauge, are similar to those experienced with sutureless cataract phacoemulsification. A decrease in intraoperative time, patient discomfort (suture and nonsuture related), and postoperative inflammation has been reported.[19-21] There have also been reports of less surgery induced astigmatism and more rapid visual recovery.[22,23]

Comparison between 20-gauge and 25-gauge vitrectomy revealed the time saved was localized to the 'initial' and 'final' steps of the procedure. The 'initial' steps included conjunctival dissection, port creation, and infusion line placement as compared to cannula insertion. The 'final' steps referred to wound closure as compared to cannula removal.[6] Again, mention should be made of the possibility of increased time for vitrectomy in particular scenarios, thus not reducing total surgical time when utilizing smaller gauge systems.

Damage to the conjunctiva is also minimalized with a transconjunctival, sutureless approach. This will be of clinical significance in those patients requiring glaucoma filtration surgery in the future. This benefit is also relevant to those few patients undergoing multiple vitreoretinal procedures.

Wound healing has been analyzed by UBM of sclerotomies in both rabbits and human eyes. Fujii *et al*,[24] claimed the small diameter of 25-gauge instruments and wounds allow for elastic recoil of the sclera to play a part in the self-sealing nature of the wound. UBM studies in rabbit sclera following 25-gauge TSV procedures confirmed this claim as well as identifying that the episclera sealed at day five and evidence of total wound closure at day nine postoperatively.[25]

Comparison of 25-gauge TSV wounds to conventional 20-gauge wounds in the same patient revealed a much faster healing rate of 15 days as opposed to 6–8 weeks, using UBM to assess the wound.[26] Kwok *et al*,[27] did not find any difference in the amount of visible vitreous incarceration between conventional sutured or sutureless sclerotomies. In regards to 25-gauge sutureless vitrectomy, there were no significant differences between oblique and direct sclerotomies.[28]

Another benefit of sutureless vitrectomy is its ability to be performed under topical anesthesia. A prospective study comparing 25-gauge and 23-gauge sutureless vitrectomy under topical 2% lignocaine gel to 25/23-gauge sutureless vitrectomy under peribulbar block showed no statistically significant difference in pain levels between the groups.[29] However, duration and the complexity of the surgery should be taken into account before performing sutureless surgery under topical anesthesia.

Complications

As with standard pars plana vitrectomy, sutureless vitrectomy has inherent complications. These include iatrogenic retinal breaks, lens touch, cataract progression, and ocular hypertension. The fact that the sclerotomies are not sutured at the end of the procedure has led to an incidence of wound leak and subsequent ocular hypotony.[20,24,30] Assessment of the wound and any obvious leak can be rectified with suture placement at the time of surgery.

Endophthalmitis is a devastating complication associated with any intraocular surgery. Concerns have been made regarding the possibility of an increase in its incidence related to sutureless procedures, including vitrectomy. Overall rates of postoperative endophthalmitis are quoted as 0.1%[31,32] with published rates following vitrectomy as low as 0.039%.[33] Kunimoto *et al*,[34] undertook a retrospective, interventional comparative cohort study aimed at assessing the incidence of endophthalmitis following 25-gauge vitrectomy and comparing it to the rate following 20-gauge vitrectomy. They found a statistically significant higher rate in the 25-gauge group of 0.23% as compared to 0.018% in the 20-gauge group. This represents a 12-fold higher incidence. Although the presence of an unsutured wound has been implicated in the increased incidence, it has also been postulated that the reduced flow rates, resulting in decreased washing effect by the infusion could be responsible. Interestingly, in all of the endophthalmitis cases, no air/fluid exchange was undertaken and these eyes may have had inferior wound integrity as a result. The wounds were largely nonbeveled in this series.

The rate of 12 times higher relative risk of endophthalmitis in 25-gauge sutureless vitrectomy compared to 20-gauge sutured vitrectomy as reported by Kunimoto *et al*,[34] must be regarded with caution as the study design was not optimal for assessing the incidence of such a rare complication. Martidis *et al*,[35] using the sutureless cataract endophthalmitis rates as an example, identified that in order to rule out an increased incidence of 2.5 times, a prospective study design would require at least 34,000 eyes per group.

Scott *et al*,[36] undertook a computerized database search aimed at comparing endophthalmitis rates between standard 20-gauge vitrectomy and 25-gauge TSV between January 2005 and December 2006 at various institutions. The endophthalmitis rate was 0.03% in 20-gauge versus 0.84% in 25-gauge vitrectomy. Only 1307 had a 25-gauge procedure compared to 6375 in the 20-gauge group. The wound construction was a straight incision in 8 of the 11 cases. The median IOP at day one was 13 mm Hg (range 5–27 mm Hg), and subconjunctival antibiotic prophylaxis was used in 9 cases. None of the eyes had fluid–gas exchange.

Singh *et al*,[37] demonstrated that the key issue, regardless of instrument gauge, is the construction of an angled or oblique wound to avoid leakage. The use of fluid/gas exchange has been shown to improve the self-sealing nature of the oblique wounds by pressing the internal wound lips together.[38]

Other complications reported with sutureless vitrectomy include decompression retinopathy,[39] postoperative retinal detachment,[40] retinal breaks[41], and intraoperative instrument breakage.[42] Increased instrument flexibility, a result of their smaller gauge, as well as increased time for an oil fill have been highlighted as limiting factors in certain posterior segment procedures by many vitreoretinal surgeons. Currently, a fragmatome cannot be used for dropped lens matter for either the 25-guage or 23-guage system; however, one is being developed for the 23-guage system.

Outcomes

With the increasing popularity of small gauge, sutureless vitrectomy, there are emerging reports outlining outcomes with significant numbers to help elucidate indications, benefits, and potential complications. Lakhanpal *et al*,[20] reported a series of 140 consecutive cases. No intraoperative complications were reported or conversion to larger gauge procedures was required. Only 7.1% of cases required single suture placement at the end of the procedure due to bleb formation, of which half had their wound enlarged to allow greater tissue manipulation. Intraocular inflammation was reduced with no inflammation detectable by 4 weeks. This compares favorably with 20-gauge studies which revealed faint to moderate inflammation in almost 50% of patients examined.[43,44] Operative time was quoted as 17.4 +/- 6.9 minutes.

A series of 77 consecutive cases that underwent 23-gauge vitrectomy for a variety of posterior segment disease, which included simple vitreous hemorrhage, macular hole, and epiretinal membrane peeling, was reported by Fine *et al*.[45] Findings included a net operating time of 24.1 minutes (7.1–74.6), no choroidal detachments, or peri-operative retinal tear or detachment. However, there were two patients who presented with IOP of less than 6 mm Hg at day one postoperatively, and one patient who required a suture at the end of surgery due to persistent leak. Also, there was one case of sterile endophthalmitis, which was not associated with postoperative hypotony.

O'Reilly *et al*,[30] reported 39 consecutive cases with hypotony (25.6%), the main postoperative complication. There were, however, no hypotony related problems such as endophthalmitis or choroidal detachments.

Kim *et al*,[46] reported a retrospective, consecutive interventional case series of 40 eyes that underwent 23-guage sutureless vitrectomy for a variety of reasons ranging from epiretinal membrane, vitreous hemorrhage to macular hole and retinal detachment, with no serious complications reported.

A series of 81 eyes was reported by Tewari *et al*,[22] focusing on visual outcomes following 23-gauge vitrectomy. Main outcome measures included visual acuity, IOP, and intro-operative and postoperative complications. They found a statistically significant improvement in vision with this system for cases with epiretinal membrane, macular hole, diabetic macular edema, and nonclearing vitreous hemorrhage. They also reported one intraoperative retinal tear treated with cryopexy at the time, and only two cases of hypotony (IOP < 8 mm Hg) which self-resolved and were not associated with choroidal detachments.

Longer term outcomes with mean follow-up of greater than one year were reported by Ibarra *et al*.[40] They conducted a retrospective, noncomparative case review of 45 consecutive eyes that underwent 25-gauge sutureless vitrectomy. There were no complications related to the sutureless nature of the procedures identified.

Our experience (unpublished data) has also shown comparable results both with 23-guage and 25-guage systems. Eighty-eight eyes of 85 patients underwent successful 25-gauge vitrectomy for various vitreoretinal disorders as follows: idiopathic macular holes (10), epiretinal membrane (20), tractional retinal detachment (8), vitreomacular traction syndrome (9), nonresolving vitreous hemorrhage (25), rhegmatogenous retinal detachment (10), endophthalmitis (2), and vitreous floaters (3). The median Snellen converted logMAR visual acuity improved from hand movement to 0.3 at 6-months postoperatively. No procedure required conversion to 20-gauge vitrectomy. Four eyes (3.4%) were noted to have retinal detachment at 6 weeks follow-up and all were successfully repaired by a second procedure, which was also sutureless. None of the eyes developed endophthalmitis or persistent hypotony or choroidal detachment. Postoperative hypotony (IOP < 6 mm Hg) was seen in five eyes (4.25%) on day one which became normal at one week follow-up in both the cases. No further case of low IOP was noted.

Fifty-five eyes of 52 patients underwent 23-gauge vitrectomy for various vitreoretinal pathology. Four eyes (7.2%) had postoperative hypotony noted on day one, which normalized in all, except one eye at week one. One eye which had persistent hypotony at week one developed peripheral choroidal detachment which self-resolved by four weeks. No other complications occurred.

A wide range of vitreoretinal procedures have been undertaken using small gauge, sutureless vitrectomy. Between 23- and 25-gauge systems, there are few, if any scenarios that will require a sutured 20-gauge approach. Even the use of silicone oil has been successfully described using a 23-gauge sutureless system.[15,47] The innovation of a trocar system for use in 20-gauge sutureless vitrectomy raises questions as to the necessity of smaller gauge systems. Studies are required to assess wound competence and resulting complications using this technique.

Another consideration is the cost–benefit ratio of utilizing this new technique. Estimates in the United States have placed the cost of a sutureless procedure 3.5 times higher than a standard sutured 20-gauge procedure.[48] This amounts to a significant increase, noticed especially in countries relying heavily on government funded healthcare. This has to be weighed against the potential savings in patient comfort and visual recovery.

Conclusion

Overall, TVS presents an exciting, innovative technique with improved patient comfort and often decreased operating times. Visual outcomes are comparable, if not more rapidly achieved and the safety profile is acceptable. Attention must be focused on wound stability at the end of each procedure with a suture placed if leak is persistent. Further prospective, comparative studies are required to gain a real understanding of its safety profile, especially in regards to the incidence of endophthalmitis. Increasing use and surgeon familiarity, as well as modifications of instruments will see this technique increasingly utilized for the entire range of vitreoretinal procedures.

References

1. Machemer R, Buettner H, Norton EW, Parel JM. Vitrectomy: A pars plana approach. Trans Am Acad Ophthalmol Otolaryngol 1971;75:813-20.
2. Kwok AK, Tham CC, Lam DS, Li M, Chen JC. Modified sutureless sclerotomies in pars plana vitrectomy. Am J Ophthalmol 1999;127:731-3.
3. O'Malley C, Heintz RM Sr. Vitrectomy with an alternative instrument system. Ann Ophthalmol 1975;7:585-8,91-4.
4. Chen JC. Sutureless pars plana vitrectomy through self-sealing sclerotomies. Arch Ophthalmol 1996;114:1273-5.
5. de Juan E Jr, Hickingbotham D. Refinements in microinstrumentation for vitreous surgery. Am J Ophthalmol 1990;109:218-20.
6. Fujii GY, De Juan E Jr, Humayun MS, Pieramici DJ, Chang TS, Awh C, *et al*. A new 25-gauge instrument system for transconjunctival sutureless vitrectomy surgery. Ophthalmology 2002;109:1807-12;discussion 13.
7. Eckardt C. Transconjunctival sutureless 23-gauge vitrectomy. Retina 2005;25:208-11.
8. Bronner A, Nemeth-Wasmer G. Vitreous body. Arch Ophtalmol Rev Gen Ophtalmol 1972;32:593-602.
9. Magalhaes O Jr, Chong L, DeBoer C, Bhadri P, Kerns R, Barnes A, *et al*. Vitreous dynamics: Vitreous flow analysis in 20-, 23-, and 25-gauge cutters. Retina 2008;28:236-41.
10. Magalhaes O Jr, Maia M, Maia A, Penha F, Dib E, Farah ME, *et al*. Fluid dynamics in three 25-gauge vitrectomy systems: Principles for use in vitreoretinal surgery. Acta Ophthalmol (Oxf) 2008;86:156-9.
11. Fang SY, Deboer CM, Humayun MS. Performance analysis of new-generation vitreous cutters. Graefes Arch Clin Exp Ophthalmol 2008;246:61-7.
12. Hubschman JP, Gupta A, Bourla DH, Culjat M, Yu F, Schwartz SD. 20-, 23-, and 25-gauge vitreous cutters: Performance and characteristics evaluation. Retina 2008;28:249-57.
13. Lopez-Guajardo L, Pareja-Esteban J, Teus-Guezala MA. Oblique sclerotomy technique for prevention of incompetent wound closure in transconjunctival 25-gauge vitrectomy. Am J Ophthalmol 2006;141:1154-6.
14. Shimada H, Nakashizuka H, Mori R, Mizutani Y, Hattori T. 25-gauge scleral tunnel transconjunctival vitrectomy. Am J Ophthalmol 2006;142:871-3.
15. Oliveira LB, Reis PA. Silicone oil tamponade in 23-gauge transconjunctival sutureless vitrectomy. Retina 2007;27:1054-8.
16. Milibak T, Suveges I. Complications of sutureless pars plana vitrectomy through self-sealing sclerotomies. Arch Ophthalmol 1998;116:119.

17. Gotzaridis EV. Sutureless Transconjunctival 20 Gauge pars plana Vitrectomy. Semin Ophthalmol 2007;22:179-83.
18. Lafeta AP, Claes C. Twenty-gauge transconjunctival sutureless vitrectomy trocar system. Retina 2007;27:1136-41.
19. Chen E. 25-Gauge transconjunctival sutureless vitrectomy. Curr Opin Ophthalmol 2007;18:188-93.
20. Lakhanpal RR, Humayun MS, de Juan E Jr, Lim JI, Chong LP, Chang TS, *et al*. Outcomes of 140 consecutive cases of 25-gauge transconjunctival surgery for posterior segment disease. Ophthalmology 2005;112:817-24.
21. Rizzo S, Genovesi-Ebert F, Murri S, Belting C, Vento A, Cresti F, *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 Ophthalmol 2006;244:472-9.
22. Tewari A, Shah GK, Fang A. Visual outcomes with 23-gauge transconjunctival sutureless vitrectomy. Retina 2008;28:258-62.
23. Yanyali A, Celik E, Horozoglu F, Nohutcu AF. Corneal topographic changes after transconjunctival (25-gauge) sutureless vitrectomy. Am J Ophthalmol 2005;140:939-41.
24. Fujii GY, De Juan E Jr, Humayun MS, Chang TS, Pieramici DJ, Barnes A, *et al*. Initial experience using the transconjunctival sutureless vitrectomy system for vitreoretinal surgery. Ophthalmology 2002;109:1814-20.
25. Zhengyu S, Fang W, Ying F, Qinghua Q. The experimental research of rabbit's sclerotomy sites undergoing transconjunctival sutureless vitrectomy. Curr Eye Res 2007;32:647-52.
26. Keshavamurthy R, Venkatesh P, Garg S. Ultrasound biomicroscopy findings of 25 G Transconjuctival Sutureless (TSV) and conventional (20G) pars plana sclerotomy in the same patient. BMC Ophthalmol 2006;6:7.
27. Kwok AK, Tham CC, Loo AV, Fan DS, Lam DS. Ultrasound biomicroscopy of conventional and sutureless pars plana sclerotomies: A comparative and longitudinal study. Am J Ophthalmol 2001;132:172-7.
28. Lopez-Guajardo L, Vleming-Pinilla E, Pareja-Esteban J, Teus-Guezala MA. Ultrasound biomicroscopy study of direct and oblique 25-gauge vitrectomy sclerotomies. Am J Ophthalmol 2007;143:881-3.
29. Theocharis IP, Alexandridou A, Tomic Z. A two-year prospective study comparing lidocaine 2% jelly versus peribulbar anaesthesia for 25G and 23G sutureless vitrectomy. Graefes Arch Clin Exp Ophthalmol 2007;245:1253-8.
30. O' Reilly P, Beatty S. Transconjunctival sutureless vitrectomy: Initial experience and surgical tips. Eye 2007;21:518-21.
31. Aaberg TM Jr, Flynn HW Jr, Schiffman J, Newton J. Nosocomial acute-onset postoperative endophthalmitis survey: A 10-year review of incidence and outcomes. Ophthalmology 1998;105:1004-10.
32. Mamalis N, Kearsley L, Brinton E. Postoperative endophthalmitis. Curr Opin Ophthalmol 2002;13:14-8.
33. Eifrig CW, Scott IU, Flynn HW Jr, Smiddy WE, Newton J. Endophthalmitis after pars plana vitrectomy: Incidence, causative organisms, and visual acuity outcomes. Am J Ophthalmol 2004;138:799-802.
34. Kunimoto DY, Kaiser RS. Incidence of endophthalmitis after 20- and 25-gauge vitrectomy. Ophthalmology 2007;114:2133-7.
35. Martidis A, Chang TS. Sutureless 25-gauge vitrectomy: Risky or rewarding? Ophthalmology 2007;114:2131-2.
36. Scott IU, Flynn HW Jr, Dev S, Shaikh S, Mittra RA, Arevalo JF, *et al*. Endophthalmitis after 25-gauge and 20-gauge pars plana vitrectomy: Incidence and outcomes. Retina 2008;28:138-42.
37. Singh RP, Bando H, Brasil OF, Williams DR, Kaiser PK. Evaluation of wound closure using different incision techniques with 23-gauge and 25-gauge microincision vitrectomy systems. Retina 2008;28:242-8.
38. Rizzo S, Genovesi-Ebert F, Vento A, Miniaci S, Cresti F, Palla M. Modified incision in 25-gauge vitrectomy in the creation of a tunneled airtight sclerotomy: An ultrabiomicroscopic study. Graefes Arch Clin Exp Ophthalmol 2007;245:1281-8.
39. Rezende FA, Regis LG, Kickinger M, Alcantara S. Decompression retinopathy after 25-gauge transconjunctival sutureless vitrectomy: Report of 2 cases. Arch Ophthalmol 2007;125:699-700.
40. Ibarra MS, Hermel M, Prenner JL, Hassan TS. Longer-term outcomes of transconjunctival sutureless 25-gauge vitrectomy. Am J Ophthalmol 2005;139:831-6.
41. Okuda T, Nishimura A, Kobayashi A, Sugiyama K. Postoperative retinal break after 25-gauge transconjunctival sutureless vitrectomy: Report of four cases. Graefes Arch Clin Exp Ophthalmol 2007;245:155-7.
42. Inoue M, Noda K, Ishida S, Nagai N, Imamura Y, Oguchi Y. Intraoperative breakage of a 25-gauge vitreous cutter. Am J Ophthalmol 2004;138:867-9.
43. Bannerman TL, Rhoden DL, McAllister SK, Miller JM, Wilson LA. The source of coagulase-negative staphylococci in the Endophthalmitis Vitrectomy Study: A comparison of eyelid and intraocular isolates using pulsed-field gel electrophoresis. Arch Ophthalmol 1997;115:357-61.
44. Tardif YM, Schepens CL, Tolentino FI. Vitreous surgery: XIV, Complications from sclerotomy in 89 consecutive cases. Arch Ophthalmol 1977;95:229-34.
45. Fine HF, Iranmanesh R, Iturralde D, Spaide RF. Outcomes of 77 consecutive cases of 23-gauge transconjunctival vitrectomy surgery for posterior segment disease. Ophthalmology 2007;114:1197-200.
46. Kim MJ, Park KH, Hwang JM, Yu HG, Yu YS, Chung H. The safety and efficacy of transconjunctival sutureless 23-gauge vitrectomy. Korean J Ophthalmol 2007;21:201-7.
47. Siqueira RC, Gil AD, Jorge R. Retinal detachment surgery with silicone oil injection in transconjunctival sutureless 23-gauge vitrectomy. Arq Bras Oftalmol 2007;70:905-9.
48. Lewis H. Sutureless microincision vitrectomy surgery:unclear benefit, uncertain safety. Am J Ophthalmol 2007;144:613-5.

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