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Minimally Invasive Vitreoretinal Surgery (25G, 27G) with High-speed Vitrectomy Cutter – Case Series

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Abstract:

Introduction: The development of vitreoretinal surgery is inseparably linked to the gradual miniaturization and decreasing invasiveness of the procedure. The smallest available systems are 23G, 25G, and 27G, which are referred to as minimally invasive vitreoretinal surgery techniques. This paper presents the preoperative and postoperative results of three patients undergoing posterior vitrectomy using the 25G or 27G systems with the HIPERVIT probe (Alcon, USA). The effects were retrospectively analyzed in terms of changes in best corrected visual acuity, intraocular pressure, occurrence of complications, and changes in optical coherence tomography images of macular edema. Examinations were performed before and one day, two weeks, three months, and six months after vitrectomy. The potential benefits and drawbacks of using these systems in practice were analyzed.

Case report: The analysis concerns the results of the performed posterior vitrectomy procedure in patients with full-thickness macular hole, tractional retinal detachment due to diabetic retinopathy, and vitreomacular traction syndrome.

Conclusions: The performed procedures allowed for improvement in both anatomical and functional conditions of the macula. All analyzed patients showed an improvement in visual acuity. None of the analyzed patients required the use of scleral sutures. Serious complications were not observed during the surgery or during the 6-month observation period. 25G and 27G HYPERVIT vitrectomy can be successfully used in the discussed vitreoretinal diseases. In the discussed cases, it enabled the effective and safe performance of the procedure.

Key words: microincision vitrectomy surgery (MIVS), vitrectomy (PPV), ophthalmology, retina.

Introduction

On July 20, 1970, Robert Machemer and his team conducted the first pars plana vitrectomy (PPV) using 17 G (1.42 mm) diameter tools. Further development of this technology was made by O'Malley and Heintz, who in 1974 created the three-port 20G (0.9 mm) vitrectomy. This was achieved by separating the cutting part, infusion and illumination, originally combined in one tool. The era of small incision surgery was initiated by Eugen de Juan in 1990 by proposing the use of 25G (0.5 mm) PPV vitrectomy [1]. The development of this technology was significantly hindered by insufficient illumination of the surgical field, significant flexibility of the tools used, and their limited availability. Gradual improvement in the parameters of the tools used allowed for the development of transconjunctival, sutureless systems – 23G (0.65 mm) and 25G [2]. Claus Eckardt played a significant role in popularizing the first one, utilizing the advantages of both 20G and 25G systems [3]. The smallest currently used system is 27G (0.4 mm), introduced for the first time by Oshima and colleagues in 2010 [4]. Tools from 23G, 25G, and 27G systems are used for minimally invasive vitrectomy techniques (MIVS).

The introduction of new minimally invasive systems was associated with concerns about a higher risk of postoperative complications such as hypotonia or endophthalmitis [5]. The preferred cutting technique turned out to be the use of tunnel sclerotomies, involving the creation of oblique, layered incisions. This technique allowed self-sealing of the wound. Inspection of each port after surgery and active search for leakage is considered as another safety measure.

Among the basic tools used during vitrectomy are: trocars, fiber optic, microforceps, microscissors infusion cannula, laser probe, flute needle, diathermy, and vitrector. In order to gain access to the vitreous body and retina, a cutting knife and trocar are used. Knives cause the formation of a linear sclerotomy, which, in the case of a smaller diameter of the tools used, does not require the application of scleral sutures. The trocar is a type of cannula inserted into the incision, which allows for the safe introduction of instruments into the eye. The construction of trocars varies between manufacturers and solutions containing valves are often preferred. This technology ensures stabilization of the pressure in the vitreous body chamber, reducing the risk of complications, including suprachoroidal hemorrhage or collapse of the vitreous body. A certain difficulty in this technology may be the introduction of instruments with a soft tip, as in the case of a flute needle.

The fiber optic enables the propagation of light, allowing the visualization of the internal structures of the eyeball. Its sources are most often xenon, halogen lamps, and lamps based on light-emitting diode (LED) technology. The tools used allow for adjustment of the angle of incidence of light or its intensity. Manual endoillumination devices usually emit a narrower beam of light and require constant work by one of the operator's hands. An alternative or additional source of light may be overhead lighting, which, when placed in one of the ports, illuminates a wide angle and allows for bimanual operation.

The microforceps is used for tissue dissection. There are many variants of this device covering different sizes, shapes, or angles of curvature. One of the applications may be, for example, peeling the retinal membrane from the surface of the retina.

Microscissors are used for tissue dissection and cutting. During horizontal cutting, they can be useful for delamination, and in the case of vertical cutting, for segmentation.

The infusion cannula placed in the vitreous chamber maintains constant pressure and allows safe exchange of fluids and gases during vitrectomy.

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The flute needle in MIVS has a soft silicone tip, which improves the safety of work near the retina. Its mechanism is based on the gradient between the higher pressure inside the eyeball and the lower atmospheric pressure, which allows fluid aspiration.

The endolaser utilizes the photocoagulation effect, which involves converting light energy into thermal energy, causing controlled damage to the retina. Its effectiveness depends on the distance between the laser tip and the retina, power, working time or retinal pigmentation. The most commonly used lasers emit green light, absorbed by melanin and hemoglobin, less frequently infrared light, which penetrates deeper. Indications for use do not differ significantly from those for slit lamp lasers and include, among others, laser therapy for degenerations, holes, tears, detachments, proliferative diabetic retinopathy, or diabetic macular edema.

Diathermy is a technique used to stop bleeding, mark the boundaries of retinal holes or mark the edges of retinotomy. It can be uni- or bipolar, utilizing the action of an electric arc to induce the coagulation effect.

A key tool for the success of the procedure is the vitreous cutter (vitrector). This device simultaneously cuts and aspirates surrounding tissues, and removes pathological membranes, vitreous fragments, hemorrhagic masses, and membranes. According to Hubschmann et al., the ideal vitrector should have the longest possible duty cycle, a large internal diameter, a sharp cutting edge, and the highest possible flow rate[6]. Other factors influencing flow rate include number of cuts, flexibility of the vitreous body, and the size of the vitrector tip opening. To increase flow, the diameter of the tools or the suction force can be increased. Unfortunately, increasing the second parameter may be associated with increased retinal traction by the aspirated vitreous body [7]. A potential solution to this problem in mechanical vitrectors may be to increase the speed of cuts, which allows the fragments of aspirated vitreous to be shortened, resulting in higher suction efficiency and flow rate [7]. Moreover, by moving the vitrector away from the retina, the operator can reduce the development of traction [8]. In pneumatic vitrectors, a negative correlation exists between the increase in the number of cuts and the flow rate. A longer cycle time may solve this limitation. In this study, a pneumatic vitrector was used, which cuts both during opening and closing of the guillotine, doubling the number of cuts. The analysis includes the results of three vitrectomy procedures using 25G or 27G Alcon (Alcon, USA) systems with a HIPERVIT probe (Alcon, USA). Pre- and postoperative results were analyzed retrospectively for changes in best corrected visual acuity (BCVA), intraocular pressure (IOP), occurrence of complications, and changes in optical coherence tomography (OCT) images of maculae. The study was performed before and one day, 2 weeks, 3 months, and 6 months after vitrectomy surgery.

Case description

The vitrectomy procedure involved three patients, as follows:

- ✓ Patient 1. – Full-thickness macular hole secondary to vitreoretinal traction;
- ✓ Patient 2. – Tractional macular detachment in the course of proliferative diabetic retinopathy;
- ✓ Patient 3. – Vitreomacular traction.

After obtaining informed consent from the patients, the procedure was performed under general anesthesia with the use of mydriatic drops – 1% tropicamide and 5% phenylephrine. After preparing a sterile field and disinfecting the conjunctival sac with a 5% povidone iodine solution, the vitrectomy was performed. In all patients, the procedure began with three tunnel sclerotomies at a distance of 3.5 mm from the corneal limbus in the upper nasal and upper and lower temporal quadrants. In the first case, the inverted flap technique was used. In the second patient, traction release and endolaser therapy were performed. In the case of the third patient, vitreomacular traction release was also performed. Endotamponade with SF6 gas 25% was applied. None of the patients required sutures for scleral wounds. After the vitrectomy procedure, eye drops containing 5 mg/ 1 ml levofloxacin and 1 mg/ ml dexamethasone were applied four times daily for a period of two weeks.

The results of the best-corrected visual acuity and intraocular pressure are presented in Tables I and II. After temporary worsening on the first day after surgery, each of the analyzed patients experienced an improvement in visual acuity. None of the patients required the use of IOP-lowering drops. No intraoperative complications were observed. In the first day after vitrectomy, minor subconjunctival hemorrhages were observed near sclerotomies. On OCT:

- ✓ patient 1: In the second week after vitrectomy, the presence of subretinal fluid and isolated intraretinal fluid spaces in the inner and outer nuclear layers was noted. By the third month after vitrectomy, these changes resolved;
- ✓ patient 2: In the second week after vitrectomy, isolated intraretinal fluid spaces in the outer nuclear layer were observed. These changes persisted until the end of the observation period;
- ✓ patient 3: In the second week after vitrectomy, isolated; intraretinal fluid spaces in the outer nuclear layer were observed. These changes persisted until the end of the observation period. Hyperreflective material in the subretinal space persisted throughout the entire observation period (Tab. II).

Patient	Diagnosis	Age	Sex
1. – 25 G	FTMH, VMT	73	Woman
2. – 27 G	VMT, DME, PDR, RD	63	Man
3. – 25 G	VMT, AVMD	71	Woman

Tab. I. Full-thickness macular hole (FTMH), vitreomacular traction (VMT), retinal detachment (RD), proliferative diabetic retinopathy (PDR), adult vitelliform macular dystrophy (AVMD).

Patient	BCVA before surgery	BCVA one week after surgery	BCVA 2 weeks after surgery	BCVA 3 months after surgery	BCVA 6 months after surgery
1. – 25 G	0.4	CF	0.5	0.7	1.0
2. – 27 G	0.03	CF	0.1	0.2	0.63
3. – 25 G	0.32	CF	0.5	0.63	0.63

Tab. II. Best corrected visual acuity. CF – counting fingers.

Patient	IOP before surgery	IOP 1 day after surgery	IOP 2 weeks after surgery	IOP 3 months after surgery	IOP 6 months after surgery
1. – 25 G	10 mmHg	14 mmHg	15 mmHg	14 mmHg	12 mmHg
2. – 27 G	17 mmHg	19 mmHg	21 mmHg	21 mmHg	20 mmHg
3. – 25 G	13 mmHg	21 mmHg	18 mmHg	16 mmHg	16 mmHg

Tab. III. Intraocular pressure measurements.

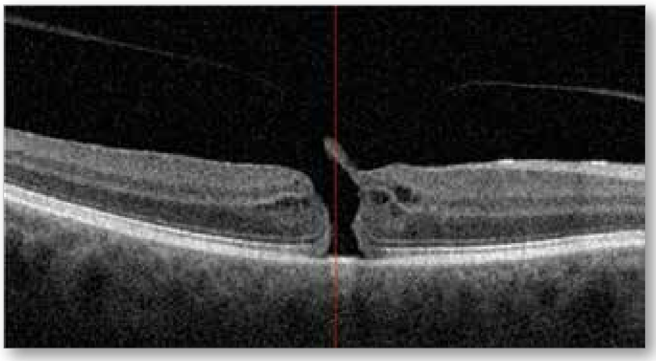


Fig. 1. OCT of macula before vitrectomy surgery – patient 1.

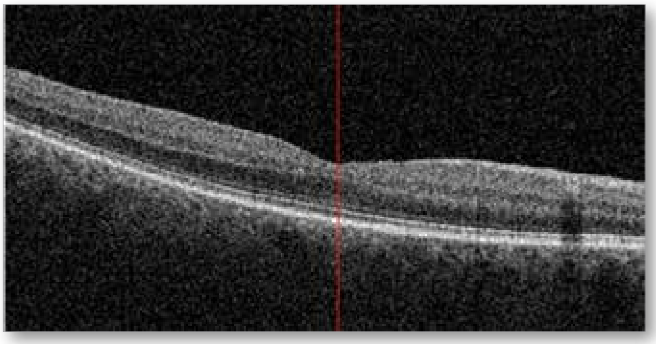


Fig. 2. OCT of macula 6 months after vitrectomy surgery – patient 1.

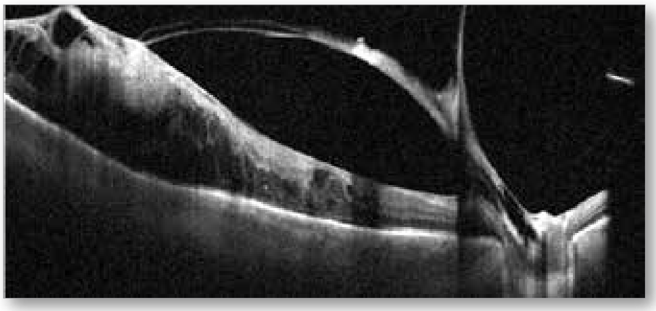
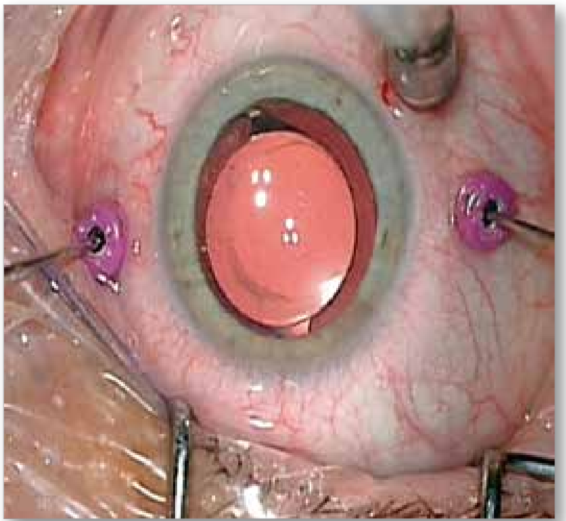


Fig. 3. OCT of macula before vitrectomy surgery – patient 2.

Fig. 4. OCT of macula 6 months after vitrectomy surgery – patient 2.



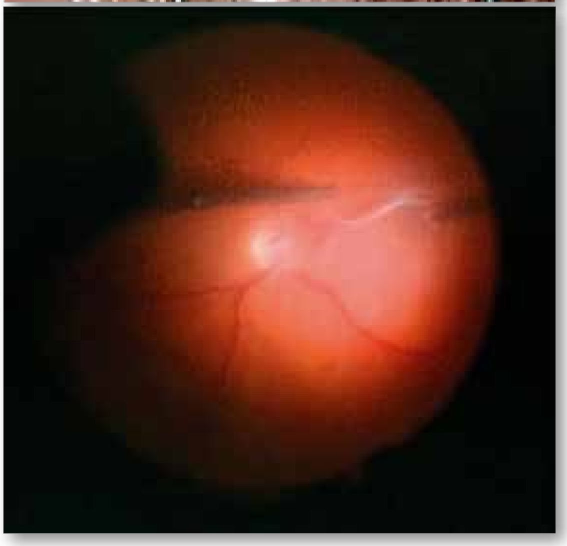


Fig. 5 and 6. Intraoperative images during vitrectomy – patient 2.

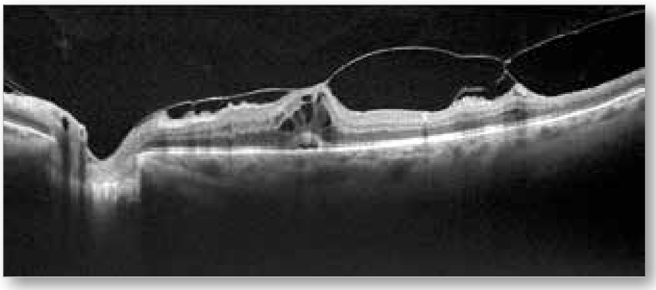


Fig. 7. OCT of the macula before vitrectomy – patient 3.

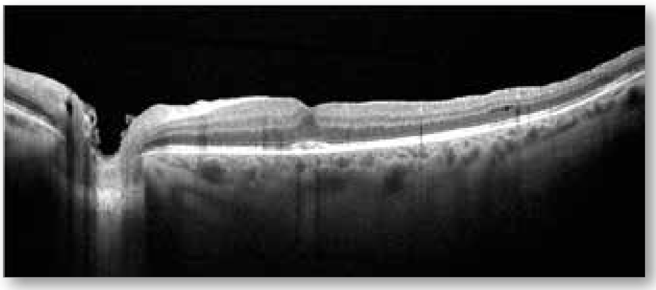


Fig. 8. OCT of the macula six months after vitrectomy – patient 3.

Conclusions

The tested HYPERVIT vitrector is available in the 25G and 27G and was developed through gradual improvement of previous technologies used in the CONSTELLATION system. The previously used Advanced ULTRAVIT allowed 10,000 cuts/minute to be achieved. In the HIPERVIT system (Alcon, USA), this number has been doubled, reaching 20,000 cuts/minute. The dual-blade technology allowed the number of cuts to be doubled. Combined with the "slit" type of tip opening it reduces retinal traction and extends the duty cycle. Furthermore, it enables a constant flow with reduced fluidic turbulence [9]. Additional technologies were implemented in this system, such as placing the opening closer to the vitrectomy tip or using a beveled tip, which allows safer work at a shorter port-to-surface distance. This is particularly impor-

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tant in macular surgery, reducing the risk of iatrogenic retinal breaks [10].These improvements may also reduce the use of scissors or forceps during segmentation or delamination.

A frequently mentioned drawback of MIVS systems is the low flow rate during vitrectomy, which can prolong surgery. This is particularly true for systems with a smaller diameter, such as 27G [8]. In the case of the 27G HIPERVIT system (20,000 cuts/ minute), studies on an animal model showed an increase in the vitreous body flow in the probe by 26–32% and a decrease in traction force by 31–41% compared to the Advanced ULTRAVIT 27G probe (10,000 cuts/minute). In case of the 25G HIPERVIT system, the vitreous flow increased by 44–47% and the traction force decreased by 20–28% compared to the Advanced ULTRAVIT 25G probe (10,000 cuts/ minute) [11]. Perhaps, with development of this technology, these parameters will further improve.

All patients achieved an improvement in visual acuity. Transient worsening of vision on the first day may be associated with the short-term effect of the applied gas endotamponade. Single intraretinal fluid spaces such as those seen in patients 2 and 3 may occur and persist after macular surgery [12]. Due to their location in the subfoveal area, they did not significantly affect the final visual acuity. The hyperreflective material in the subretinal space in patient 3 is more likely associated with AVMD.

No serious intraoperative or postoperative complications were observed in any of the patients. Scientific studies have repeatedly confirmed the safety of MIVS systems [13, 14]. Early considerations regarding the higher risk of hypotony or endophthalmitis did not limit the spread of this technology [15]. However, the technique of creating ports, the learning curve of a given technique for the operator, postoperative antibiotic therapy, adherence to aseptic principles, and proper peripheral vitrectomy are all significant factors influencing the occurrence of these complications [16]. Authors such as Allen Chiang et al. emphasize the impact of the chosen endotamponade on the risk of endophthalmitis as well [17].

There was no need for scleral suture placement after sclerotomy in any of the operated patients. The use of smaller sclerotomies reduces scleral trauma, which is associated with better patient comfort, lower postoperative astigmatism [18], a shorter procedure time and a shorter recovery period [5]. The use of the 27G system, compared to 25G, is associated with a lower rate of complications related to sclerotomy healing while maintaining similar anatomical and functional outcomes [19].

Initially, the flexibility of tools and lower flow values limited the use of MIVS. Increase in the number of cuts, improvement in flow parameters, and enhancement of tool stiffness changed it. Its potential applications in the treatment of diseases such as rhegmatogenous and tractional retinal detachments or PDR [20]. have gradually expanded. In PDR treatment, precise removal of membranes and proliferations while working at short distances from the retina is particularly important, as observed in the cases discussed.

All operated patients experienced improvement in visual acuity and, as mentioned, no serious intraoperative and postoperative complications were observed. This fact may indicate effectiveness and safety of the performed procedures. The use of smaller sclerotomies obviated the need for postoperative scleral sutures, thereby mitigating the invasiveness of the procedure. In conclusion, despite certain technological limitations associated with the miniaturization of surgical tools, MIVS systems are constantly being improved, offering hope for the development of further solutions that combine precision and efficiency in the future.

Disclosure
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References:

1. De Juan E. Jr, Hickingbotham D: *Refinements in microinstrumentation for vitreous surgery*. Am J Ophthalmol. 1990; 109(2): 218–220.
2. Fujii GY, De Juan E Jr., Humayun MS, et al.: *A new 25-gauge instrument system for transconjunctivalsutureless vitrectomy system for vitreoretinal surgery.* Ophtahlmology. 2002; 109(10): 1807–1812; discussion 1813.
3. Eckardt C: *Transconjunctival sutureless 23-gauge vitrectomy.* Retina. 2005; 25: 208–211.
4. Osawa S, Oshima Y: *Innovations in 27-gauge vitrectomy for sutureless microincision vitrectomy surgery*. Retina Today. 2014; July/ August: 42–45.
5. Thompson JT: *Advantages and limitations of small gauge vitrectomy.* Surv Ophthalmol. 2011 Mar-Apr; 56(2): 162–172. doi: 10.1016/j.survophthal.2010.08.003. Epub 2011 Jan 14. PMID: 21236459.
6. Hubschman JP, Gupta A, Bourla DH, et al.: *20-, 23-, and 25-gauge vitreous cutters: performance and characteristics evaluation.* Retina. 2008 Feb; 28(2): 249–257. doi: 10.1097/IAE.0b013e31815ec2b3. PMID: 18301030
7. Rossi T, Querzoli G, Angelini G, et al.: *Introducing new vitreous cutter blade shapes: a fluid dynamics study.* Retina. 2014 Sep; 34(9): 1896–1904. doi: 10.1097/IAE.0000000000000143. PMID: 24871998.
8. Teixeira A, Chong L, Matsuoka N, et al.: *Novel method to quantify traction in a vitrectomy procedure.* Br J Ophthalmol. 2010 Sep; 94(9): 1226–1229. doi: 10.1136/bjo.2009.166637. Epub 2010 Jun 10. PMID: 20538657.
9. Rossi T, Querzoli G, Angelini G, et al.: *Introducing new vitreous cutter blade shapes: a fluid dynamics study*. Retina. 2014 Sep; 34(9): 1896–1904. doi: 10.1097/IAE.0000000000000143. PMID: 24871998.
10. Jairath NK, Paulus YM, Yim A, et al.: *Intra- and post-operative risk of retinal breaks during vitrectomy for macular hole and vitreomacular traction.* PLoS One. 2022 Aug 11; 17(8): e0272333. doi: 10.1371/journal.pone.0272333. PMID: 35951646; PMCID: PMC9371285.
11. Steel DH, Charles M, Zhu Y, et al.: *Fluidic performance of a dual-action vitrectomy probe compared with a single-action probe*. Retina. 2022 Nov 1; 42(11): 2150–2158. doi: 10.1097/IAE.0000000000003573. Epub 2022 Jul 21. PMID: 35868025; PMCID: PMC9584060.
12. Frisina R, Pinackatt SJ, Sartore M, et al.: *Cystoid macular edema after pars plana vitrectomy for idiopathic epiretinal membrane.* Graefes Arch Clin Exp Ophthalmol. 2015 Jan; 253(1): 47–56. doi: 10.1007/s00417-014-2655-x. Epub 2014 May 25. PMID: 24859385.
13. Recchia FM, Scott IU, Brown GC, et al.: *Small-gauge pars plana vitrectomy: a report by the American Academy of* Ophthalmology. Ophthalmology. 2010; 117(9): 1851–1857.
14. Khan MA, Shahlaee A, Toussaint B, et al.: *Outcomes of 27 gauge microincision vitrectomy surgery for posterior segment disease*. Am J Ophthalmol. 2016; 161: 36–43.
15. Oshima Y, Wakabayashi T, Sato T, et al.: *A 27-gauge instrument system for transconjunctival sutureless microincision vitrectomy surgery.* Ophthalmology. 2010 Jan; 117(1): 93–102.e2. doi: 10.1016/j.ophtha.2009.06.043. Epub 2009 Oct 31. PMID: 19880185.
16. Baudin F, Benzenine E, Mariet AS, et al.: *Epidemiology of Acute Endophthalmitis after Intraocular Procedures: A National Database Study.* Ophthalmol Retina. 2022 Jun; 6(6): 442–449. doi: 10.1016/j.oret.2022.01.022. Epub 2022 Feb 5. PMID: 35134544.zz
17. Chiang A, Kaiser RS, Avery RL, et al.: *Endophthalmitis in microincision vitrectomy: outcomes of gas-filled eyes*. Retina. 2011 Sep; 31(8): 1513–1517. doi: 10.1097/IAE.0b013e3182209290. PMID: 21878799.
18. Tekin K, Sonmez K, Inanc M, et al.: *Evaluation of corneal topographic changes and surgically induced astigmatism after transconjunctival 27-gauge microincision vitrectomy surgery*. Int Ophthalmol. 2018; 38: 635–643.
19. Ma J, Wang Q, Niu H: *Comparison of 27-Gauge and 25-Gauge Microincision Vitrectomy Surgery for the Treatment of Vitreoretinal Disease: A Systematic Review and Meta-Analysis*. J Ophthalmol. 2020 Aug 18; 2020: 6149692. doi: 10.1155/2020/6149692. PMID: 32908682; PMCID: PMC7450297.
20. Shroff CM, Gupta C, Shroff D, et al.: *Bimanual microincision vitreous surgery for severe proliferative diabetic retinopathy: outcome in more than 300 eyes.* Retina. 2018 Sep; 38 Suppl 1: S134–S145. doi: 10.1097/IAE.0000000000002093. PMID: 29406470.

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