

The use of silicone oils with viscosity of 1000 cs and 5000 cs in vitrectomy procedures: a literature review



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HIGHLIGHTS

Silicone oil endotamponade stabilizes the retina after vitrectomy; oil type and viscosity should be individualized to reduce complications.

ABSTRACT

Silicone oil endotamponade is an important element of vitreoretinal surgery, especially in the treatment of complex and recurrent retinal detachments. The most commonly used oils are 1000 cs and 5000 cs viscosities. The aim of this paper is to review the current knowledge regarding their use, with particular emphasis on indications, anatomical efficacy, and complications. Literature analysis indicates that both oils provide comparable final retinal attachment. The 5000 cs oil is more resistant to emulsification but more difficult to use, while the 1000 cs oil is easier intraoperatively but more susceptible to emulsification. The choice of viscosity should be individualized.

Key words: silicone oil 1000 cs, silicone oil 5000 cs, retinal detachment, vitrectomy, proliferative vitreoretinopathy, PVR

INTRODUCTION

Silicone oil endotamponade is applied post vitrectomy surgery. It acts as long-term mechanical reinforcement to retinal tissues, forming a direct link between retina and pigment epithelium, so the integrity of breaks in the retina can regenerate and heal [1, 2]. Although most common intraocular tamponades in vitrectomy are also gas-filled, their material and clinical attributes reveal a separate need. Gases such as C_3F_8 (perfluoropropane) are buoyant and have much better retinal contact than silicone oils. Gas tamponade has a significantly superior performance in closure of macular holes and visual acuity outcomes compared to silicone tamponade with fewer required reoperations than that obtained with these substances, which justifies its application in the routine cases of macular defects and retinal detachment without proliferative signs and symptoms. Gases can be absorbed faster, therefore without the presence of surgical tamponade removal and to expedite patient rehabilitation [3]. Nevertheless, silicone oils have an additional action that is also advantageous in some clinical cases. For instance, in severe, chronic situations such as proliferative vitreoretinopathy (PVR), traumatic detachments, or devastating retinal diseases, especially with prolonged stability of the tamponade required to promote healing and prevent re-detachment, they should be used more carefully compared to other oils used or placed in more extreme treatment settings. Under these circumstances, silicone oil is selected as the product with the highest potential for long term (prolonged) effect [4]. But knowing the limitations of silicone oils is important, we know this however must be the limit of what silicone oil use does.

SILICONE OIL ENDOTAMPONADE. CLINICAL BASICS

Clinical silicone oils are hydrophobic, chemically stable compounds. Yet normally the oil may float in the vitreous cavity because in many cases it is less dense than water. A second classification consists of heavy silicone oils, which have a density higher than water. Depending on retinal pathology, detachment, and PVR will determine which silicone oil is used. Standard silicone oils, these are the oils with a lower density than water, float at the upper quadrants of the eye and can be a good tamponade for the upper and central quadrants of the retina. They are the standard technique for retinal detachments that are dominant in upper fields of retinal pathology, after supramacular breaks, and for more durable, stable tamponade that is not dependent on rigid patient positioning [4–6]. In comparison, heavy oils like Densiron and Oxane HD will maintain a higher density than aqueous humour and therefore will penetrate into the inferior quadrants of vitreous cavity. This characteristic gives them a particular edge over silicone oil and gas in retinal detachment disorders, inferior breaks, re-

current detachment of PVR with predominance in the inferior quadrants and for a deficiency of adequate tamponade of the inferior fields in classic silicone oil or gas [6–8]. Wilson et al. comparative studies reveal similar anatomical endpoints with respect to retinal adhesion status of heavy and standard silicone oils. They differ in performance in the control of inferior retinal fields and complication profile but have similar anatomical endpoints in terms of retinal adhesion status [7]. Łatkowska et al. (2014) have shown use of heavy oils to prevent subsequent loss of the lower quadrant; however, the inflammation, rapid emulsification, and development of complications with the anterior segments with heavy oils means that heavy oil use is limited to specific and focused indications [4, 6–8]. On this basis, HSOs are not considered everyday tamponade, however, are a clinical solution for highly problematic cases [4, 6] (tab. 1).

TABLE 1

Comparison of silicone oils depending on their density.

Clinical aspects	Silicone oils with a density lower than water	Silicone oils with a density higher than water
Density relative to water	lower	higher
Direction of tamponade	towards the upper quadrants	towards the lower quadrants
Typical clinical indications	upper retinal detachments, complex cases requiring long-term tamponade, PVR without inferior predominance	lower retinal detachments, recurrent detachments with dominant PVR in the inferior regions
Anatomical effectiveness	comparable	comparable
Nature of use	standard tamponade in most cases	selective tamponade for specific cases

PVR – proliferative vitreoretinopathy.

CLINICAL INDICATIONS FOR THE USE OF SILICONE OIL ENDOTAMPONADE

Silicone oil endotamponade is specifically designed for patients whose risk for long-term retinal anatomical stabilization with recurrent retinal detachment is high. Main indications include retinal detachment secondary to PVR, wherein silicone oil dampens tractional forces generated by proliferative membranes while stabilizing the retina throughout the restorative phase, thereby minimizing the risk for surgical failure of PVR [4–6]. An important example to keep in mind is multiple retinal breaks and giant tears, as stable and uniform tamponade over a large retinal area is required. In contrast to gases, silicone oil provides long-term stable retinal anatomy regardless of tamponade resorption, which is crucial in cases of extensive peripheral retinal injury [5, 6] (tab. 2).

TABLE 2

Indications for endotamponade with silicone oil.

Clinical situation	Problem characteristics	Rationale for silicone oil use
Retinal detachment with proliferative vitreoretinopathy	presence of proliferative membranes and vitreoretinal traction	long-term retinal stabilization, reduced traction forces, and reduced risk of recurrent detachment
Recurrent retinal detachment	failure of prior surgical treatment	need to ensure stable, long-term tamponade after subsequent intervention
Multiple retinal breaks	multiple lesions of the peripheral retina	even tamponade of a large retinal surface, independent of resorption
Giant tears	a tear involving $\geq 90^\circ$ of the retinal periphery	stable retinal support and reduced risk of secondary traction
Penetrating injuries to the eyeball	retinal injuries, intraocular haemorrhages, vitreous humour, anatomical instability	long-term stabilization of intraocular structures and retinal protection

THE IMPORTANCE OF SILICONE OIL VISCOSITY IN CLINICAL PRACTICE

In clinical vitreoretinal surgery, silicone oils with 1000 cs and 5000 cs viscosity are some of the most frequently employed as they have distinct properties in terms of endotamponade preservation and can lead to complications after operation. Increased viscosity of the silicone oil implies increased molecular weight and increase in the polydimethylsiloxane chain length, which, owing to the greater resistance to shear forces, can theoretically be less affected by emulsification, particularly in the case of long-term intraocular tamponade [9–11]. Emulsification is one of the reported complications related to silicone oil application and remains one of the most important factors restricting the potential for retention of silicone oil in the vitreous cavity in a safe way [2, 5, 12]. And while there is a physical property of 1000 cs and 5000 cs oils being dissimilar in viscosity, clinical studies still need to be carried out, which did not reveal a definitive and powerful difference in end-point structural effectiveness in retinal detachment therapy. Abu-Yaghi et al. have reported a notable high rate of the attachment to the eye (anatomical) irrespective of the viscosity of long-term silicone oil tamponade, which is highly predictive of potential complications (e.g., increased pressure in the eye, oil emulsification and corneal modification) [12]. The authors found no significant differences in final retinal attachment rates across groups, suggesting that the anatomical performance for complicated retinal detachment of both viscosities did not differ significantly. Additional authors concluded similarly that the selected oil viscosity neither influenced nor hindered the success of anatomical treatment, especially in patients with PVR [13, 14]. As for complication profile, silicone oil emulsification is most commonly observed with low viscosity oil due to a low-

er mechanical resistance against forces introduced by eye movement and aqueous humour [10, 15]. According to Tayyab et al. the emulsification rate among 5000 cs oil was low; however, it was detected with longer tamponade time with a higher risk of use beyond 8–10 weeks [15]. Besides viscosity, other studies have pointed out that many factors influence the emulsification process, such as the presence of blood in the vitreous, inflammation, past operation, and the retention time in the eye [2, 5]. Silicone oil with a viscosity of 1000 cs has an injected and delivered technique, from the standpoint of surgery. On the other hand, 5000 cs oil is recommended for the patient at whom stable tamponade becomes necessary for extended periods in advanced proliferative vitreoretinopathy, for recurrent retinal detachments or reoperation as a result of its high viscosity [12–14]. Nevertheless, processing of 5000 cs silicone oil might lead to long operative time and possibility of tissue loss after removal of the oil [10, 11]. Silicone oils that have a viscosity of 1000 cs compared to 5000 cs showed a similar anatomical efficacy in treatment of retinal detachment confirming the results of past retinal detachment research. Viscosity parameters should be adjusted based on anticipated application time, case complexity, emulsification risk, and surgeon experience, not theoretical physical properties of the oil [2, 5, 12–14] (tab. 3).

TABLE 3

Comparison of 1000 cs and 5000 cs silicone oils.

Feature/Clinical application	Silicone oil 1000 cs	Silicone oil 5000 cs
Viscosity	lower	higher
Shear resistance	lower	higher
Susceptibility to emulsification	higher, with prolonged tamponade	lower
Simplicity of surgery	easier injection and extraction, shorter procedure time	more difficult manipulation, longer removal time
Standard primary retinal detachment	preferred	less frequently chosen
Advanced proliferative vitreoretinopathy	less frequently chosen	preferred
Recurrent retinal detachments/reoperations	less frequently chosen	preferred
Long-term tamponade (>3 months)	less frequently chosen	preferred
Risk of increased IOP	comparable	comparable

IOP – intraocular pressure.

COMPLICATIONS ASSOCIATED WITH SILICONE OIL ENDOTAMPONADE

Emulsification is the single most significant problem in applying silicone oil as an endotamponade as it is a significant

reason for the increase of postoperative complications during vitrectomy. Due to emulsification, the oil, which was once a homogeneous mass, breaks down into numerous microdroplets that can migrate to various ocular structures, such as the anterior chamber, drainage angle, and corneal endothelial surface [4, 6]. According to Łatkowska et al. [4–6], these encourage emulsification when oil's viscosity is low, oil remains in the eye for an extended period of time, blood or proteins infiltrate the tissue in the vitreous cavity, and strong eye movements induce shear forces at the oil-water interface. Oils containing greater viscosity (5000 cs) have higher emulsification resistance compared to 1000 cs oils, but this difference does not completely eliminate the emulsion risk, particularly with long-term tamponade [4, 6, 8]. Oils with heavy viscosity have received more attention as their higher density and complexity promote early emulsion and subsequent inflammatory response compared to conventional silicone oils. This phenomenon restricts their long-term usage and is one of the primary determinants of the selective use of these preparations for defined clinical indications [6–8]. Emulsification does far more than just present oil in small droplets. Migratory emulsions interfere with the flow of aqueous humour, induce anterior segmental changes in the eye, provoke chronic inflammation, and precipitate early postoperative complications [4–6]. As such, emulsification has been recognized as one of the predominant pathophysiological mechanisms underlying the association of chronic silicone oil exposure to complications. The most widespread form of this is accelerated cataract formation. This happens when the oil emulsion touches the posterior lens capsule, which disrupts its metabolism, halts nutrient diffusion, and promotes progressive opacification [12, 16]. A further major effect is raised intraocular pressure, which can result in secondary glaucoma if not treated properly. This increase may be due to the migration of scattered droplets that obstruct the flow of aqueous humour in the posterior chamber of the eye as the droplets accumulate in the pupillary aperture, leading to pupillary blockage. Iridectomy is a potential approach as an additional drainage route. Droplets can also move into the anterior chamber, where deposition at the drainage angle obstructs aqueous humour reabsorption, resulting in increased pressure [1, 15, 17]. In aphakic or pseudophakic patients, who lack or have damaged the natural barrier, this mechanism puts them at greater risk [1, 15, 17]. Abu-Yaghi et al. showed patients receiving high-viscosity oil had a clinically meaningful increase in intraocular pressure. They also report cases of patients treated with endotamponade who had variable visual acuity. Discrepancies in visual outcome were found over the years in the entire cohort, and these variations were significant at both preoperative and at initial postoperative visits. Compared with baseline data and first postoperative examination in the 1000 cs tamponade group visual acuity analysis (BCVA) was significantly

decreased with an increase in no visual acuity after assessment. Additionally, a significant decrease in the visual acuity in the 5000 cs oil group was observed as early as the first postoperative day, whereas measurements conducted after the visit did not indicate a significant difference compared to postoperative follow-up visits. These findings support that an immediate reduction in visual acuity could be observed on vitrectomy with tamponade with silicone oil, regardless of the viscosity of the tamponade and may be due to both transient intraocular environmental factors and early postoperative retinal injury in the first postoperative months of rehabilitation. While there was no clear evidence of a subsequent significant decrease in BCVA in either arm of the study, early visual deficit might warrant an examination of visual response and suggest a potential route of short term changes in visual function during the first few weeks after tamponade [12]. Retinal detachment secondary to silicone oil removal may develop prematurely and results in retinal detachment prior to complete regaining position. The likelihood of recurrent detachment is comparatively high among patients undergoing multiple surgical operations with wide proliferative changes [13, 18]. Another complication is keratopathy, which results when the oil migrates into the anterior chamber and enters the corneal endothelial cells. Severe exposure to this fluid results in endothelial damage, decompensation and corneal oedema and opacification, impairing vision considerably [2, 19]. Other authors also caution against incidental vision loss, not associated with primary retinal injury. In the type of patients described by Pakravan et al. following retinal detachment surgery with silicone oil endotamponade, the patients had a major deficit in vision that could not be explained by classical causes, such as reoperations or PVR. The authors note that this type of complication can happen with standard viscous oils and heavy silicone oils, and still can occur despite the satisfactory anatomical retinal attachment after retinal surgery [20]. Although the mechanisms of this complication remain unknown, the neurotoxicity of silicone oil on photoreceptors and retinal cells and the accompanying alterations in microvascular circulation have been suggested as important contributors. This highlights both importance of monitoring the visual function in patients after endotamponade and consideration of the duration of silicone oil in the eye, which may need to be limited in order to prevent catastrophic, irreversible loss of vision (tab. 4).

CONCLUSIONS

Silicone oil endotamponade is advised for at least 3 months to provide structural reinforcement of the retina following vitrectomy (for most patients). This is the minimum amount of time required to heal a retinal break and to minimize the possibility for early recurrence of detachment. This is a compromise between the length it takes to perform tamponade

TABLE 4

Complications of silicone oil endotamponade.

Complication	Pathophysiological mechanism	Clinical consequences
Silicone oil emulsification	disintegration of a continuous mass of oil into microdroplets; migration of the emulsion into the anterior segment of the eye	the starting point for numerous secondary complications
Accelerated cataract development	contact of the oil emulsion with the posterior lens capsule, disruption of nutrient metabolism and diffusion	progressive lens opacification, decreased visual acuity
Increased IOP/secondary glaucoma	pupillary block caused by oil droplets, angle closure, impaired aqueous humour outflow	chronic IOP increase, risk of optic nerve damage
Decreased visual acuity	early changes in the intraocular environment, intraoperative effects, and the impact of oil on the ocular optics	transient or persistent
Secondary retinal detachment	too early removal of the oil before full retinal stabilization	recurrence of detachment, need for reoperation
Keratopathy	migration of the oil into the retinal chamber anterior corneal oedema, corneal endothelial damage	corneal oedema, opacities, decreased vision
Unexplained vision loss	potential toxic effects of oil on photoreceptors, microcirculation disorders	permanent deterioration of visual function despite retinal attachment

IOP – intraocular pressure.

and the complications of long-term maintenance due to the presence of oil in the eye. Clinically, most recommend a 3 to 6 month [1, 11, 13, 15] duration of service, which is the longest length of time for which such an intervention is recommended according to medical practice. It has been found that prolonged endotamponade duration over 6 months generally represents a high risk and a significant potential for silicone oil emulsification, elevated intraocular pressure, keratopathy, and visual complaints. Studies have shown that higher viscosity oils (such as 5000 cs) are less emulsifying than 1000 cs for long-term tamponade. This difference does have clinical relevance when the oil is required in the eye for a longer duration but does not negate the likelihood of complications in general nor does it clearly indicate that long-term therapy is more detrimental when administered once [1, 11, 13, 15]. So far, available studies have not revealed a clear benefit of one type of silicone oil in total postoperative complications, pointing out the value of individualized treatment selection. As a result, continued and systematic ophthalmological monitoring for silicone oil endotamponade is critical to the patient's early postoperative period, as well as for monitoring tamponade therapy. Conventional monitoring involves visual acuity checking and periodic intraocular pressure assessment important for the progressive complication of secondary glaucoma, as well as anterior segment biomicroscopy to detect possible migration of the oil emulsion into the anterior chamber. Fundus examination is another important component of follow-up, as it can also evaluate retinal adhesion and recognize warning signs of recurrent detachment.

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Cite as: Gołda M, Dziecioł K, Sirek S et al. The use of silicone oils with viscosity of 1000 cs and 5000 cs in vitrectomy procedures: a literature review. *Ophthalmotherapy*. 2026; 13(2): A290926.

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Mikołaj Gołda: lead author, organising systematic review, collecting, analysing and interpreting the literature, preparing the draft version, editing the text and drafting the conclusion.

Karina Dzieciot: literature analysis, literature selection, assessment of the methodological quality.

Sebastian Sirek: coordination, scientific supervision, ensuring methodological correctness, substantive support, verification.

Dorota Wyględowska-Promieńska: scientific supervision, ensuring methodological correctness, editing the final version, ensuring coherence and clarity in the presentation of results.

Conflict of interest:

None.

Financial support:

None.

Ethics:

The content presented in the article complies with the principles of the Helsinki Declaration, EU directives and harmonized requirements for biomedical journals.