



Original article

Correlation of spectral domain optical coherence tomography findings in sub-silicone oil foveal depression space and visual outcome in eyes undergoing silicone oil removal



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ABSTRACT

Background/Purpose: To describe small hyper-reflective spherical bodies in sub-silicone oil-foveal depression (SSO-FD) space using spectral domain optical coherence tomography (SD-OCT) and its effect on visual outcomes in eyes undergoing silicone oil removal (SOR).

Methods: This was a prospective interventional comparative study comprising 42 eyes undergoing SOR with clear media. All patients underwent detailed clinical examination and SD-OCT scan of fovea preoperatively and at 30 days and 90 days postoperatively. Patients were divided into Group A ($n = 21$) and Group B ($n = 21$) depending on presence or absence, respectively, of small hyper-reflective spherical bodies in the SSO-FD space in preoperative scans. The findings between SD-OCT and best-corrected visual acuity were correlated and analyzed.

Results: The mean age of patients was 41.9 years (range, 23–60 years) in Group A and 45.6 years (range, 23–60 years) in Group B. Twenty-one eyes showed small hyper-reflective spherical bodies on SD-OCT imaging. These were thought to represent emulsified silicone oil globules trapped in the potential space created by silicone oil meniscus and foveal pit, which is the SSO-FD space. These bodies were absent in all post SOR scans of Group A and Group B. Group A had significant visual improvement ($p = 0.0001$) after SOR with clearance of these hyper-reflective bodies as compared to Group B ($p = 0.356$).

Conclusion: We conclude that these small hyper-reflective spherical bodies in the SSO-FD space were most likely emulsified silicone oil globules and correlated with significant visual improvement with their clearance after silicone oil removal.

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1. Introduction

Silicone oil (polydimethylsiloxane) is a linear synthetic polymer composed of repetitive Si–O units and meets all the requirements for intraocular use and can be considered as the ideal material for intraocular tamponade.¹ Cibis et al² first reported the use of silicone oil in vitreoretinal surgery in 1962. Later Scott³ and Zivojnovic et al⁴ used this technique in the treatment of complicated retinal

detachments with proliferative vitreoretinopathy. In the current era, the use of silicone oil as a surgical tamponade has become a standard technique in the treatment of retinal detachments, especially in proliferative vitreoretinopathy and tractional retinal detachments, severe cases of diabetic retinopathy, endophthalmitis, viral retinitis, and ocular trauma.⁵

Emulsification of silicone oil is a well-known phenomenon that is encountered in patients who have had silicone oil tamponade for variable periods leading to secondary complications. Although recommendations range from 3 months to 6 months, there is still no definite agreement on the optimal removal time.^{6–8} There is scant scientific knowledge about the *in vivo* emulsification process of silicone oil intraocularly. Experimental and histopathology studies have shown that silicone oil droplets

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are deposited within the retinal tissues, optic nerve, and anterior segment structures including the cornea, uveal tissue, and trabecular meshwork.^{9–12}

Chung and Spaide¹³ reported the use of first-generation OCT to demonstrate intraretinal silicone oil vacuoles in a single patient who underwent macular hole surgery with internal limiting membrane peeling and temporary silicone oil tamponade. Another study by Errera et al¹⁴ reported the use of SD-OCT in the detection of epiretinal, intraretinal, or subretinal hyper-reflective areas and hypothesized it to be small bubbles of emulsified silicone.

We have noted small spherical bodies in the foveal depression below the silicone oil meniscus showing hyper-reflectivity on SD-OCT scanning. We termed these bodies as hyper-reflective spherical bodies in the subsilicone oil foveal depression (SSO-FD) space. These bodies probably interfere to some extent with central visual acuity. In our prospective comparative study, we compared a group with small hyper-reflective spherical bodies in the SSO-FD space using SD-OCT with a group with no such bodies, and established their correlation with improvement in visual acuity after silicone oil removal.

2. Methods

After Institutional Ethics Committee (Retina foundation, Ahmedabad) approval, 42 eyes of 42 patients who met with all the inclusion and exclusion criteria were enrolled in this study with informed consent. Patients who underwent primary vitrectomy with silicone oil tamponade for rhegmatogenous retinal detachment (macula off), having clear media with settled retina on clinical examination and with a minimum 3 months of post-silicone oil removal follow-up were included in the study. The same medical grade and viscosity silicone oil (1000 centistokes) was used in all patients after vitrectomy. The patients with any complications such as cataract, glaucoma, hyperoleon, or band-shaped keratopathy

hampering the OCT scan, or responsible for reduced visual acuity during follow-up of 3 months were excluded. Patients who developed repeat retinal detachments within 3 months after SOR and patients in whom foveal contours were lost due to macular pathology, such as epiretinal membrane, scarring, or macular edema, were excluded.

All patients underwent detailed clinical examination including best-corrected visual acuity (BCVA), intraocular pressure measurement and SD-OCT scans before silicone oil removal and at 30 days and 90 days postoperatively. SD-OCT examination was carried out with a Spectralis HRA+OCT device (Heidelberg Engineering, Heidelberg, Germany) equipped with an eye-tracking system for the simultaneous acquisition of near-infrared reflectance ($\lambda = 815$ nm), and SD-OCT images with an illumination wavelength of 870 nm and an acquisition speed of 40,000 A scans per second and 7 μ axial resolution. Horizontal and vertical lines as well as volume scans were performed in the morning before silicon oil removal by the surgeon. The patients were followed up at 30 days and 90 days postoperatively.

For each eye, a standard protocol of SD-OCT imaging using the horizontal and vertical scans 30° (8 mm length) and full volume scan containing 19 B scans (30° × 15°) was used. Distance between B scans: 240 μ m and 768 A scans was utilized. On follow-up visits, the same areas were scanned using the scanner software by taking progressive reference scan options so as to prevent any observer subjective bias.

Depending on the presence (Figures 1A, 2A, and 2C) or absence (Figure 3A) of small hyper-reflective spherical bodies in the SSO-FD space in preoperative scans, patients were divided into Group A and Group B. The correlations between preoperative and postoperative SD-OCT findings and BCVA were analyzed. Statistical significance was calculated based on negative ranking using Wilcoxon signed ranks test, Mann–Whitney *U* test, χ^2 and Student *t* test as appropriate.

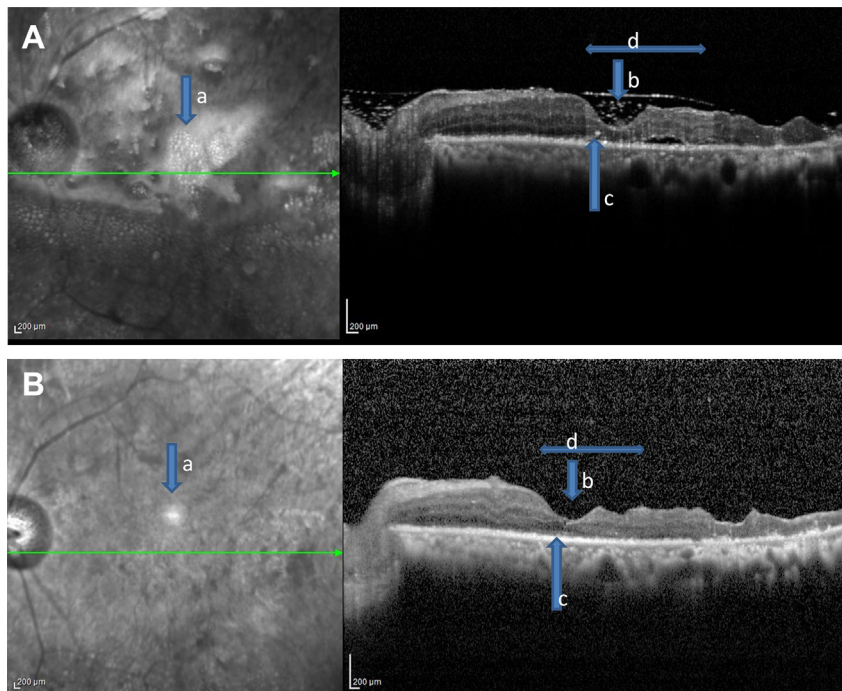


Figure 1. (A) Preoperative red-free fundus photograph and spectral domain optical coherence tomography scan in Group A showing: a, foamy glistering sheen; b, hyper-reflective bodies in sub-silicone oil-foveal depression space; with c, intraretinal hyper-reflective bodies; and d, after shadowing/back scattering on retinal layers. (B) Post-silicone oil removal red-free fundus photograph and spectral domain optical coherence tomography scanning in Group A showing: a, absence of foamy sheen; and b, no hyper-reflective bodies in sub-silicone oil-foveal depression space. The c, intraretinal hyper-reflective bodies; and d, after shadowing/back scattering on retinal layers are also absent.

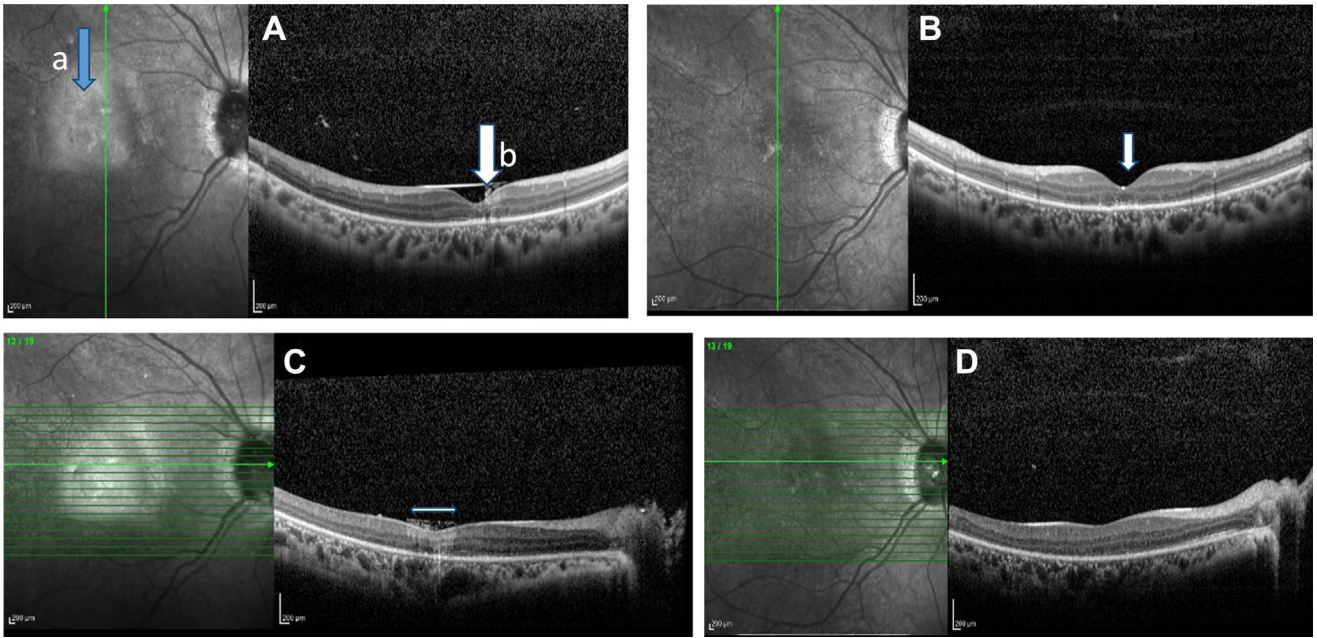


Figure 2. (A) Pre-SOR SD-OCT scanning in Group A showing: (a) altered sheen; and (b) hyper-reflective bodies in sub-silicone oil-foveal depression space with back scattering. (B) Post-SOR SD-OCT scan shows absence of altered sheen, hyper-reflective bodies, and back scattering. (C) Pre-SOR SD-OCT scanning in Group A showing hyper-reflective bodies in sub-silicone oil-foveal depression space with back scattering. (D) Post-SOR SD-OCT scan shows absence of hyper-reflective bodies and back scattering. SD-OCT = spectral domain optical coherence tomography; SOR = silicone oil removal.

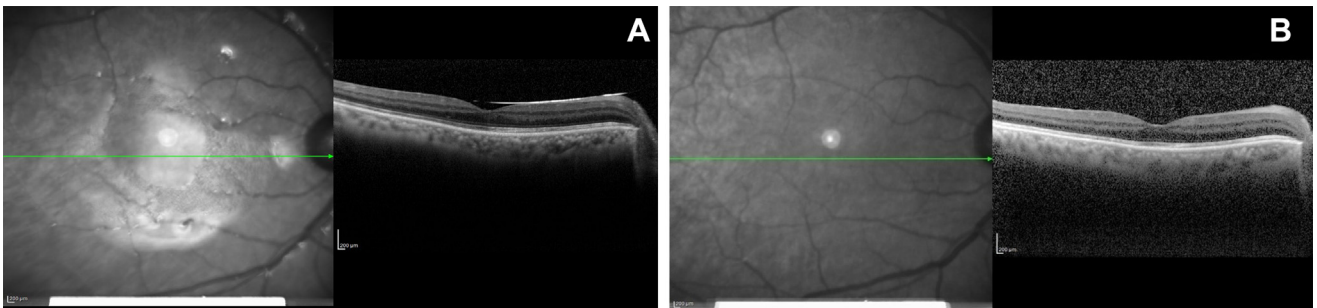


Figure 3. (A) Pre-SOR and (B) post-SOR spectral domain optical coherence tomography scanning in Group B showing absence of hyper-reflective bodies in sub-silicone oil-foveal depression space. SOR = silicone oil removal.

VISUAL OUTCOME

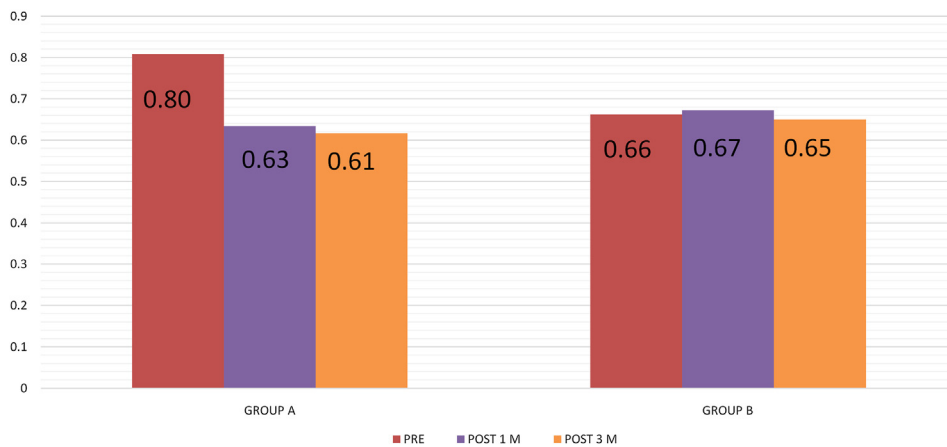


Figure 4. Mean improvement in best-corrected visual acuity at 1 month and 3 months post-silicone oil removal.

Table 1
Demographic characteristics of study population.

	Group A	Group B
Male	14 (66.7)	17 (81)
Female	7 (33.3)	4 (19)
Age (y)	41.90 ± 13.5	45.61 ± 16.9
Duration of silicone oil removal (mo)	7.19 ± 1.7	8.85 ± 3.3

Data are presented as *n* (%) or mean ± standard deviation.

3. Results

The mean age of patients was 41.9 years (range, 23–60 years) in Group A and 45.6 years (range, 23–60 years) in Group B. The mean duration of silicone oil tamponade was 7.19 ± 1.7 months in Group A and 8.85 ± 3.3 months in Group B. Group A had 66.7% male and 33.3% female patients while Group B had 81% male and 19% female patients (Table 1).

On pre-SOR SD-OCT scans, we found small hyper-reflective spherical bodies in the SSO-FD space in 21 eyes (Figures 1A, 2A, and 2C) and these cases were kept in Group A, whereas the remaining 21 eyes showed absence of any small hyper-reflective spherical bodies in the SSO-FD space (Figure 3A) and were enrolled in Group B. In addition, 47.6% of patients in Group A showed after-shadowing/back scattering due to accumulated hyper-reflective bodies on the posterior silicone oil meniscus (Figures 1A and 2C) on retinal layers. Also, 57.1% of patients in Group A showed intraretinal hyper-reflective bodies (Figure 1A).

On post-SOR SD-OCT scans, the small hyper-reflective spherical bodies were absent from the SSO-FD space in all cases in Group A (Figures 1B and 2B) and Group B (Figure 3B). The back scattering causing altered reflectivity of the retinal layers (Figures 1B and 2D) and intraretinal hyper-reflective bodies were also absent in all the post-SOR scans (Figure 1B).

The details of mean pre-SOR and post-SOR BCVA at 1 month and 3 months are shown in Table 2. The mean improvement in BCVA of Group A at 1 month was 0.173 ± 0.13 and 0.190 ± 0.18 at 3 months, which was highly significant at both 95% and 99% confidence intervals of the difference. There was no improvement seen in mean BCVA in Group B at 1 month, although it improved by 0.114 ± 0.85 at 3 months and was not statistically significant. In Group A, 90.4% of the eyes showed improvement in BCVA while in Group B, only 19% of the eyes showed improvement in BCVA at 3 months post-SOR (Figure 4). Neither the presence of altered reflectivity ($p = 0.751$) nor intraretinal hyper-reflective bodies ($p = 0.90$) correlated significantly with the visual improvement seen in Group A.

4. Discussion

Emulsification of silicone oil is a well-known phenomenon that is encountered in patients who have had silicone oil tamponade for

Table 2
Mean BCVA (pre-SOR and post-SOR) with mean improvement at 1 month and 3 months.

Mean		Group	
		Group A	Group B
Pre-SOR mean BCVA		0.807 ± 0.22	0.661 ± 0.27
Post-SOR at 1 mo	Mean BCVA	0.634 ± 0.19	0.672 ± 0.28
	Mean improvement	0.173 ± 0.13 ($p < 0.001$)	-0.010 ± 0.86 ($p = 0.583$)
Post-SOR at 3 mo	Mean BCVA	0.617 ± 0.21	0.650 ± 0.23
	Mean improvement	0.190 ± 0.18 ($p < 0.001$)	0.114 ± 0.85 ($p = 0.547$)

BCVA = best-corrected visual acuity; SOR = silicone oil removal.

variable periods. There is scant scientific knowledge about the *in vivo* emulsification process of silicone oil intraocularly. However, experimental and histopathological studies have shown that silicone oil droplets are deposited within the retinal tissues, optic nerve, and anterior segment structures including the cornea, uveal tissue, and trabecular meshwork.^{9–12} Silicone oil droplets have been seen in the retina, either in enucleated eyes or in eyes with recurrent retinal detachments and having concurrent retinal biopsy.¹⁵ Eckardt and associates¹⁵ found single intraretinal macrophages containing silicone in eyes injected with silicone oil for 2 years and showed that the retina had multiple defects in the inner limiting membrane (ILM). Ohira and coworkers¹⁶ showed that emulsified silicone oil injected into rabbit eyes appeared in the inner retinal layers as early as 1 week after injection. However, advances in OCT technology in recent times have led to increased resolution and better definition of intraocular structures such as the retina, and imaging of these small hyper-reflective spherical bodies and vacuoles is possible.

We have noted small spherical bodies in the foveal depression below the silicone oil meniscus showing hyper-reflectivity on SD-OCT scanning. We hypothesize that these small hyper-reflective spherical bodies, which most likely are emulsified silicone oil globules, are trapped in the potential space created by the silicone oil meniscus and foveal pit, which is the SSO-FD space. To the best of our knowledge, this is the first study to use SD-OCT to describe the presence of hyper-reflective areas in SSO-FD space in eyes with silicone oil tamponade. We also correlated the improvement in BCVA with clearance of these hyper-reflective bodies from the SSO-FD space after SOR, which also has not been reported yet.

A literature review also suggested that these hyper-reflective bodies are possibly emulsified silicone oil globules,^{13,14} or they could be protein aggregates/inflammatory factors/fat.^{17,18} These bodies settle in the fovea and become trapped in the foveal depression. Asaria et al¹⁷ demonstrated that concentrations of basic fibroblast growth factor, interleukin-6 and protein are raised in retro-silicone oil fluid. Jimeno et al¹⁸ demonstrated that cholesterol, fatty acids and derived methyl esters accumulate in intra-vitreal silicone oil used in intraocular tamponade. A recent case report by Welch and de Souza¹⁹ described the possibility of silicone oil microbubble formation and migration within a full thickness macular hole defect contributing to surgical failure. However, there are several observations that suggest that these hyper-reflective spherical bodies are most likely to be emulsified silicone oil.

On review of the literature, we found only two reports of OCT being used as a method to describe residual silicone oil emulsification after removal. In 2003, Chung and Spaide¹³ identified intraretinal small clear silicone oil vacuoles in the macular region where the inner limiting membrane peeling had been performed in a single patient who had undergone macular hole surgery with silicone oil tamponade. They found that these vacuoles were intraretinal cystoid spaces on first-generation OCT. Errera et al¹⁴ reported the use of SD-OCT in the detection of epiretinal, intraretinal, or subretinal hyper-reflective areas in a series of 11 patients with a history of silicone oil tamponade. They concluded that the hyper-reflective areas are likely to be small bubbles of emulsified silicone. We observed similar hyper-reflective bodies in the SSO-FD space. Errera et al¹⁴ also described identical hyper-reflective spherical bodies in anterior segment SD-OCT after injection of emulsified silicone oil into the model rubber eyes; these bodies were not present in eyes injected with water alone. The difference in reflectivity between our findings those of Chung and Spaide¹³ may be attributed to the fact that hyporeflective spaces could represent cystoid macular edema, which can occur after ILM peeling or vitrectomy using silicone oil tamponade. Also, due to technological limitations (1st-generation OCT), previously,

multimodal imaging was not performed, and the location of the vacuoles on red-free imaging could not be accurately correlated with the OCT scans. Similar limitations would mean that small, spherical, hyper-reflective bodies would not be resolved.¹⁴

We found a foamy glistening sheen in red-free photographs (Figures 1A, 2A, and 2C), which corresponded to an area of the hyper-reflective spherical SSD-FD space, which cleared along with disappearance of all these hyper-reflective bodies from all eyes after removal of silicone oil (Figures 1B, 2B, and 2D), which further supports this hypothesis.

The retinal appearance of retained perfluorocarbon liquid has been described in the literature. Perfluorocarbon liquid bubbles tend to coalesce and are detected as larger hyporeflective entities,²⁰ distinct from the smaller hyper-reflective entities that we describe. This, to a great extent, confirms that these spherical bodies are not caused by retained perfluorocarbon liquid.

In our clinical scenario, visual acuity of the patients with silicone oil tamponade is reduced due to various reasons such as oil-induced cataract, glaucoma, neuropathy, epiretinal membrane formation, loss of foveal contour, disruption of inner segment/outer segment (IS/OS) junctions, and scarring. Otherwise, the visual acuity remains unchanged in uncomplicated cases. We hypothesize that altered reflectivity of these particles, as noted in SD-OCT scans, created scotoma or some visual impairment. During the process of silicone oil removal, these bodies are washed away from the SSO-FD space and are associated with significant visual improvement. We noted mean BCVA improvement of 0.190 ± 0.18 in Group A and was highly significant at both 95% and 99% confidence intervals of the difference, while Group B did not show any significant visual improvement and remained stable. We also noted visual improvement after SOR in 90.4% of eyes that had hyper-reflective bodies in the SSO-FD space as compared to only 19% of eyes where no such bodies were noted, which further supports our hypothesis.

We found that these hyper-reflective bodies trapped posterior to the silicone oil meniscus, instead of entering the superior part of the eyeball as emulsified silicone oil bubbles, have a natural tendency to enter the superior part.

The limitations of this study were the small sample size and short follow-up. This might have limited the power in detecting other predictors and may have led to insufficiency of the statistical analysis. The 3-month follow-up seems to be appropriate for the evaluation of OCT parameters and visual outcomes, although visual outcomes additionally may improve or decrease, or both, 6 months or even 12 months after surgery. Why these bodies are trapped in the foveal depression, what do they represent, and establishing the correlation between duration of SOR and presence of these hyper-reflective bodies are future areas of research.

In conclusion, our study is believed to be the first to describe the use of SD-OCT imaging to identify *in vivo*, tiny, hyper-reflective spherical bodies in the SSO-FD space in eyes undergoing SOR. Clearing of these bodies is correlated with visual improvement after SOR. So, the preoperative presence of these spherical bodies on SD-OCT scanning can predict visual improvement and have prognostic significance. SD-OCT represents an important modality in the further investigation of the presence of possible silicone oil emulsification in the SSO-FD space and its clinical significance.

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